March 2017

Energy-Efficient Solutions: A Study of Electrical Installation Advancements in Hong Kong's Existing Commercial Buildings

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A Study of Electrical Installation Advancements in Hong Kong's Existing Commercial Buildings

An Interactive Qualifying Project submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science on March 3, 2017 by:

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Submitted to:
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Abstract

This project, sponsored by Business Environment Council Limited (BEC) in Hong Kong, developed a list of technologies recommended to increase the energy efficiency of Hong Kong's commercial buildings, and identified barriers to the adoption of energy-saving technologies. Information was gathered through desk-based research as well as interviews with building and hotel managers, property developers, technology developers and suppliers, and energy advisory consultants. The team provided BEC with the list of technologies along with their overall descriptions, cost and energy data, case studies, and explanations of advantages and disadvantages. This information will feed into a larger BEC project to create an informational guide to assist in the overall uptake of sustainable technologies.

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Acknowledgements

We would like to thank BEC for sponsoring this project, specifically Maya de Souza and Jonathan Ho for being the project liaisons and working closely with our team. They were especially helpful in getting contacts for interviews and providing advice and suggestions along the way. We would like to thank our WPI project advisors, Professors Holly K. Ault and Roger Lui, for their invaluable advice and edits throughout the project. We would like to thank our ID 2050 instructor Professor Dominic Golding for his guidance in the preparation term for our project. Finally, we would like to thank all the professionals who took the time to interview with us and to provide useful information and case studies for our report.

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Executive Summary

Hong Kong is a special administrative region (SAR) of China and is the 6th most densely populated city in the world (Demographia, 2016). Hong Kong has a carbon footprint of 6.6 tons of CO_2 per capita, 67% of which comes from electricity generation (Climate Change Business Forum, 2014). Commercial buildings alone encompass 65% of the electricity use in the city and are an important sector to focus on (EMSD, 2016k).

Business Environment Council Limited (BEC) is a non-government, business membership organization that works to promote the uptake of sustainable practices and technologies in order to reduce waste, prevent pollution, conserve resources, and improve corporate environmental and social responsibility within the Hong Kong community (BEC, 2017). They are currently working on a project entitled *The Economics of Energy Efficiency in the Built Environment – Developing the tools for making decisions on cost-effective solutions.* This project aims to provide building managers with an informational guide on new, energy-saving technologies, to help them increase the energy efficiency of their buildings, and builds on past BEC projects: *Every Building a Powerhouse* (EBP) in 2010, and *Carbon Smart Buildings* (CSB) in 2012. By providing this information to managers throughout the city, they hope to accelerate the large-scale uptake of energy-saving technologies in Hong Kong. This WPI IQP contributes to BEC's initial project phase by researching electricity saving technologies as well as focusing on stakeholder identification of barriers to the overall uptake of energy-efficient technologies in Hong Kong's commercial buildings.

Methods

The overall goal of this project was to identify, analyze, and evaluate new technologies in building lighting and mechanical systems that can reduce energy usage and costs in commercial buildings in Hong Kong and identify barriers and benefits to the widespread adoption of such technologies.

To achieve this goal, the team developed four main objectives:

Objective 1: Create a list of technologies that can best improve the energy efficiency of buildings in Hong Kong.

Objective 2: Provide descriptions, data, and analysis on each technology within the list.

Objective 3: Identify barriers and benefits to the adoption of new energy-efficient technology in Hong Kong.

Objective 4: Compile a series of case studies on technologies within the list to support the findings.

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To fulfill these objectives, the team conducted desk-based research and reviewed past BEC reports (EBP and CSB) as well as sources from the Hong Kong Electrical and Mechanical Services Department (EMSD). To supplement the desk-based research, the team conducted 16 interviews with building developers, building managers, hotel managers and developers, technology suppliers and developers, and energy advisory consultants. The team collected data from 9 questionnaires and compiled 24 case studies to provide detailed information for the technologies that could not be obtained through interviews.

Findings

Technologies

After researching 22 technologies, the team identified 14 technologies that met four criteria: The advantages of the technology should outweigh the disadvantages, the technology should be suitable for use in Hong Kong, the technology should be relatively new or not yet widely used in Hong Kong, and the technology should be within the scope of electricity saving technologies to be used in existing commercial buildings. These technologies are listed in the table below.

<table>
<tr><th colspan="12">Lighting</th></tr>
<tr><td colspan="3">LED lights</td><td colspan="3">T5 fluorescent lights</td><td colspan="3">Room occupancy sensors</td><td colspan="3">Task lighting design</td></tr>
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<tr><td colspan="2">Oil-free chillers</td><td colspan="2">Variable speed drive (VSD) air conditioning</td><td colspan="2">Variable flow control for condensing water pipes</td><td colspan="2">Heat pumps</td><td colspan="2">Variable speed drive (VSD) fans and motors</td><td colspan="2">Electronically commutated (EC) plug fans</td></tr>
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<tr><td colspan="3">Linear synchronous motor (LSM) lifts</td><td colspan="3">Regenerative braking lifts</td><td colspan="3">Lift destination control devices</td><td colspan="3">Service on demand (SOD) escalators</td></tr>
</table>

Barriers and Benefits to Adoption

The primary barriers to adopting energy-efficient technologies in commercial buildings faced by building owners, managers, and tenants are: lack of information, product lifespan, product compatibility, tenant and landlord relationships, and costs. In general, building managers and owners are aware that they should make changes to increase the energy efficiency of their buildings, but are unfamiliar with the resources available to them and are often unsure of the

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savings that can be achieved in their specific buildings. The lifespan of products is a significant deterrent to the uptake of new technologies because building owners and managers generally do not want to retrofit systems that have not yet reached the end of their lifespan. The compatibility of a new technology within the existing building systems is especially important, and most energy efficiency updates require a retrofit. Retrofits are difficult to schedule as most buildings are leased and inconvenience to the tenant must be considered. Additionally, the tenant and landlord arrangement makes the issue of who will initiate and pay for the retrofits more complex and frequently a barrier. Cost is a general barrier because the upfront costs, namely the installation, capital, and retrofit costs, for energy saving technologies are often higher than the upfront costs for less energy-efficient equivalent technologies.

Even though many energy-efficient technologies have higher upfront costs than their conventional equivalents, these additional costs can be recouped from the energy savings. The customer will be able to save additional money once they have received a payback on their investment. Furthermore, companies can improve their corporate image by using energy-efficient technologies in their properties, and a good corporate image can help companies increase their revenue as they may be preferred over other lesser-known companies and will attract customers who value sustainability.

Recommendations

Based on our research, we have identified ways to use and improve upon our research methods, additional stakeholders and experts for future interviews, potential future projects, and recommendations for building managers and owners who want to increase the energy efficiency of their buildings.

Further research can be conducted to include technologies not covered in our report. We researched three categories of technology: lighting, air conditioning, and lifts and escalators. Further research to consider would be control systems, gas usage, and smart meters, as well as additional electricity-saving technologies not included in our research.

Additional stakeholders and experts can provide information and data to supplement the findings of this report. Interviews with building and hotel managers can assist in further developing a baseline of uptake as well as understanding the target audience for the report. In addition, EMSD employees can provide further data on technologies. Surveys of tenants can provide the tenant perspective to assist building managers on how to best work with and for their tenants.

Energy usage data should be collected and monitored before planning and also after completing retrofits. Data from monitoring energy usage prior to upgrading technologies or systems can be used to identify which areas to focus retrofits on first as well as to establish a baseline of energy usage for the particular building or unit. It is also important to continue monitoring the energy usage after completing retrofits in order to evaluate the success of the retrofit, be able to track progress, and calculate savings that have been achieved.

Planning ahead for energy-efficient retrofits should be expected by building managers, and can be productively combined with other types of maintenance and modifications planning. With thoughtful planning, retrofits can be scheduled to maximize the number of technologies upgraded at once, thereby minimizing the cost, tenant disruption, and waste. These retrofits can also correspond with previously planned routine maintenance and modifications to units while they are unoccupied during a gap between tenants.

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Figures and Tables

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Glossary

Organizations and Studies Abbreviations:

BEAM (Building Environmental Assessment Method)

BEC (Business Environment Council Limited)

CSB (Carbon Smart Buildings) (2012)

EBP (Every Building a Powerhouse) (2010)

EMSD (Electrical and Mechanical Services Department - The Government of the Hong Kong Special Administrative Region)

SAR (Special Administrative Region)

SME (Small and Medium Sized Enterprises)

Technologies and Practices:

LED (Light Emitting Diode) A lighting technology in the form of a semiconductor chip that emits electromagnetic waves or light when a voltage is supplied to it.

EC (Electronically Commutated) EC plug fan or Electronically Commutated plug fan uses electronic circuitry in place of a brush to control the rotation of the motor (EBN-PAPST, 2017).

HVAC (Heating Ventilation Air Conditioning)

LSM (Linear Synchronous Motor) A type of motor that uses magnetic field induction to move objects. When used in lifts, the passenger car moves faster and the system saves energy and space by removing the traditional counterweight pulley system.

Retrocommissioning A process of evaluating the performance of an existing building's systems to identify problems in efficiency and then using this information to adjust the settings and calibrations to ensure maximum efficiency.

Retrofitting The installation of new technology, parts, or fixtures to an existing building to improve the current state of systems. Retrofitting is most often done when older building systems or components need to be replaced.

ROI (Return on Investment) A measurement of the gain or loss generated on an investment relative to the amount of money invested.

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SOD (Service on Demand) Escalators sometimes referred to as variable speed drive (VSD) escalators, use occupancy sensors to detect the presence of passengers. When no passengers are detected, the escalator will either run at low speeds (using VSDs) or stop completely to conserve energy.

VSD (Variable Speed Drive) A functionality that allows motors to operate at varying speeds, minimizing the amount of energy needed to perform the desired function, and therefore reducing the amount of energy wasted by motorized devices.

Part Load Conditions Conditions for a machine when the demand of the system is below the maximum output.

1 Introduction

Globally, nonrenewable energy resources are being rapidly depleted while the usage of renewable resources is slow to develop. With an ever-growing world population, the risk of exhausting non-renewable sources before renewable infrastructure is in place increases every year. Carbon emissions from using fossil fuels worldwide contribute to global warming. This means that it is extremely important for large cities, like Hong Kong, to increase their energy efficiency to reduce the total annual energy consumption. Hong Kong[1] is a special administrative region of China, with a population of 7.3 million people. The main sources of revenue are tourism and trade, and most residents live and work in high-rise buildings. A large portion (roughly 270 square kilometers) of the land is conserved and only 24.2% is urban or built-up land (Hong Kong Planning Department, 2016). This has led Hong Kong to become the 6th most densely populated city in the world (Demographia, 2016). Given its density, its already large population, and its popularity as both a tourist and trade destination, 98% of the buildings in the city are over 12 floors tall (Emporis, 2016) and are primarily mixed-use with residences, hotels, shopping malls, and other commercial structures in the same building. For example, a shopping mall may contain offices above it, and an MTR subway station below it. These buildings consume enormous amounts of energy through their demands for heating, cooling, and lighting in particular.

Fossil fuels are the primary sources of energy used for electricity generation in Hong Kong (Hong Kong Census and Statistics Department [C&SD], 2015). The burning of fossil fuels impacts both global warming and the depletion of nonrenewable resources. In 2008, Hong Kong's carbon footprint was 6.6 tons of CO_2 per capita in comparison with 3.9 tons per capita in mainland China (Climate Change Business Forum [CCBF], 2014). In 2016, China pledged to reduce its carbon emissions by signing the Paris Agreements (United Nations Framework Convention on Climate Change, 2016). Hong Kong plays an important role in China's ability to achieve its goal for carbon emission reductions, and 67% of Hong Kong's carbon emissions are produced from electricity generation (CCBF, 2014). Currently, commercial buildings alone account for 65% of the electricity use in the city (EMSD, 2016k). Therefore, one of the most important ways Hong Kong can reduce its carbon footprint is through the adoption of energy saving technologies in commercial buildings.

Many new devices have been designed to reduce the amount of energy consumed by buildings, yet it remains unclear whether or not the available energy-conserving technologies are

[1] All mentions of Hong Kong refer to the Special Administrative Region and not Hong Kong Island.

being fully utilized throughout the city. Business Environment Council Limited (BEC), the sponsor of this WPI project, serves to promote the uptake of clean practices and technologies to reduce waste, prevent pollution, conserve resources, and improve corporate environmental and social responsibility within the Hong Kong community (BEC, 2017). This report covers research on the energy savings potential and costs of new technologies pertaining to the mechanical and electrical systems in commercial buildings, as well as research on the current uptake and barriers to uptake, with the goal of recommending ways to reduce the amount of electricity consumed annually. The research was used to develop a list of technologies to reduce electricity consumption in existing commercial buildings, gain an understanding of the current barriers to adoption of new technologies, and gather case studies to showcase examples of energy-efficient technologies in use.

The results of this project will be used by BEC to assist in a more comprehensive project titled *The Economics of Energy Efficiency in the Built Environment – Developing the tools for making decisions on cost-effective solutions*. This larger project aims to provide building managers with a guide on new, energy saving technologies, to help them increase the energy efficiency of their buildings. Their hope is that, by providing this information to managers throughout the city, they can accelerate the large-scale uptake of these energy saving technologies in Hong Kong.

2 Background

This chapter will elaborate on the current situation of energy usage in Hong Kong, what work has been done to increase the energy efficiency of commercial buildings in Hong Kong, and provide insight on the potential to increase the energy efficiency of commercial buildings in Hong Kong.

2.1 Energy Use in Hong Kong

Electricity in Hong Kong is primarily produced from oil and coal products, (Hong Kong Census and Statistics Department [C&SD], 2015) which are fossil fuels that contribute to greenhouse emissions. There is significant potential to reduce the carbon footprint by reducing the electricity usage and increasing efficiency. While gas usage is also a factor in the overall energy consumption, it only accounts for 18% of the total energy used in Hong Kong, while electricity accounts for 55% (Figure 2.1), and thus this report focuses on reducing electricity consumption. In 2014, the total energy usage per capita was 39.93 GJ and the total electricity use per capita was 21.84 GJ (Hong Kong Electrical and Mechanical Services Department [EMSD], 2016). Population is steadily increasing in Hong Kong while the total energy use per capita and the electricity use per capita have stayed relatively constant over the last decade (EMSD, 2016k). This means that gross energy usage has been increasing at a similar rate to the population.

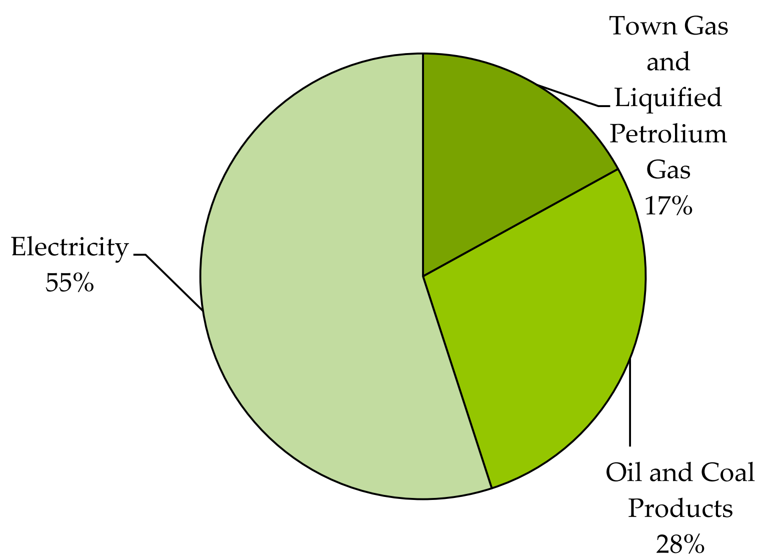

Figure 2.1: Hong Kong Energy Use by Fuel Type in 2014 (data from EMSD, 2016k)

Electricity usage is broken down by sector and by use. The commercial sector uses the most electricity (65%), followed by the residential sector (27%) (Figure 2.2). Within the commercial sector, no subsector accounts for more than 17% of electricity consumption (Figure 2.3), except for the undefined "other" category.

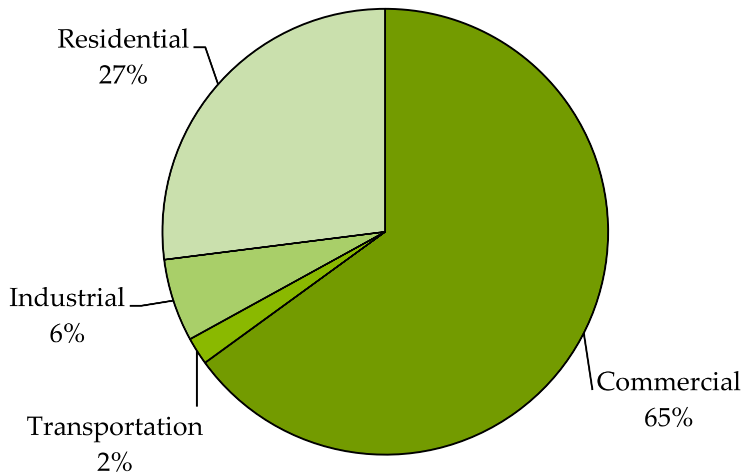

Figure 2.2: Hong Kong Electricity Use by Sector in 2014 (data from EMSD, 2016k).

Figure 2.4 shows that space conditioning and lighting are the two largest single uses of electricity in the commercial sector, along with other uses, which includes escalators and lifts. Hong Kong has a subtropical climate with cool, dry winters and hot, humid summers. The city is comprised of about 81% high-rise buildings (about 35-100 meters or 12-39 floors tall) and 17% skyscrapers (over 100 meters or 40 floors tall) (Emporis, 2016). Given the hot nature of the climate, and the design of modern high-rise buildings with sealed windows, space conditioning is a major consumer of electricity. The two primary ways to reduce the energy usage of space conditioning are either to decrease the demand by building occupants or increase the efficiency of the space conditioning equipment. Decreasing the demand is unlikely as air conditioning is a necessity in such warm temperatures and will only become more relied on as temperatures rise due to global warming. The average global temperatures have been increasing at an annual rate of 0.15-0.2°C (0.27- 0.36°F) per year (Carlowicz, 2010). In Hong Kong, the mean temperatures have risen by 0.9°C (1.62°F) from 2005 to 2015 (C&SD, 2015). As temperatures are likely to continue rising, so will the energy usage for cooling. Because space conditioning accounts for 31% of all electricity consumption in the commercial sector in Hong Kong (Figure 2.4), increased efficiency within this type of technology can make a major impact on the total energy usage.

While lighting, lifts, and escalators do not use as much of the total electricity as space conditioning, small changes add up and there is potential to reduce electricity usage in these categories. Similar to space conditioning, there is little room to reduce the use of lifts and escalators due to the prevalence of tall buildings in Hong Kong. While some of the lighting demand can be met using natural light, this is difficult because of the density of buildings and cannot be used in interior rooms or at night. Therefore the best way to reduce the energy consumption in these categories is to increase the efficiency of the technologies and systems because it is unlikely to reduce the demand and use of the electricity-using systems.

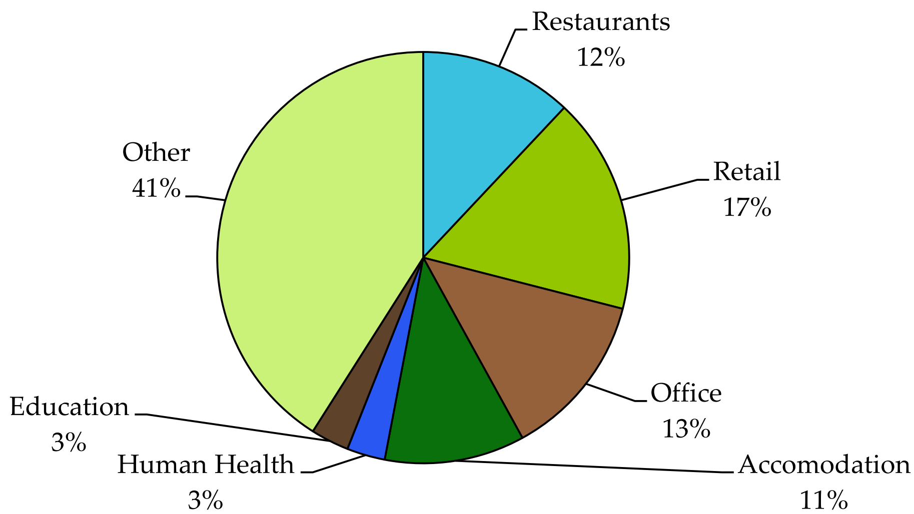

Figure 2.3: Hong Kong Electricity Use by Commercial Sector in 2014 (data from EMSD, 2016k).

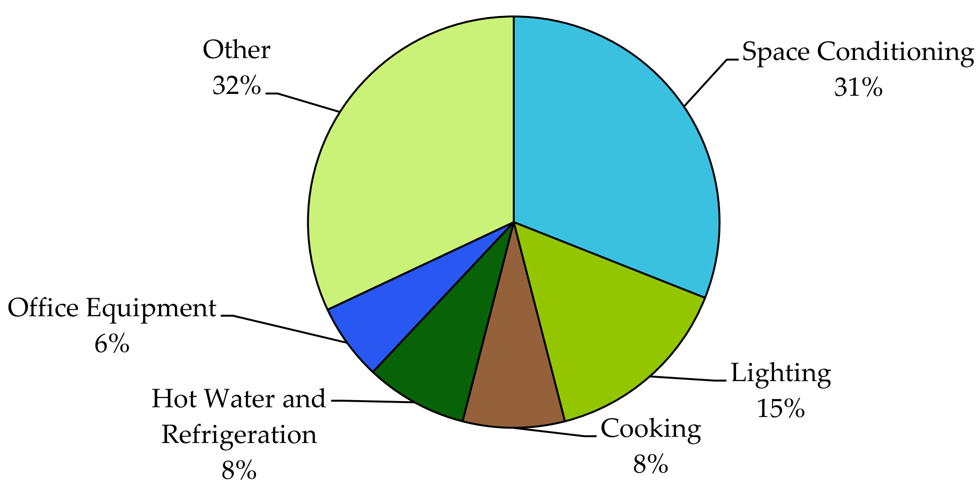

Figure 2.4: Hong Kong Electricity Consumption by End Use in the Commercial Sector in 2014 (data from EMSD, 2016k).

2.2 Hong Kong Organizations

Business Environmental Council Limited (BEC) is a non-government, business membership organization founded in Hong Kong in 2000 when the Private Sector Committee on the Environment (PSCE) and the Centre for Environmental Technology (CET) merged. Its member organizations include businesses from property development, construction, and technology sectors with a common goal of transitioning to a low carbon economy. BEC offers sustainable solutions and services that include advising, training, assessing, advocating, and conducting research to work towards its primary goal to promote the uptake of clean practices and technologies to reduce waste, prevent pollution, conserve resources, and improve corporate environmental and social responsibility within the Hong Kong community (BEC, 2017).

BEC understands that Hong Kong buildings consume a massive 89% of the SAR’s total electricity consumption (BEC's Climate Change Business Forum [BEC CCBF], 2012), and contribute 60% to Hong Kong’s total greenhouse gas emissions (Ho, 2017). Accordingly, BEC has directed several efforts to both research and develop solutions that could reduce this impact. Working together with several other organizations, BEC assisted in developing a building rating tool titled Building Environmental Assessment Method (BEAM) in 1996 (BEC, 2016a). This voluntary rating tool assesses and ranks buildings from Bronze to Platinum based on energy efficiency and sustainability (BEAM, 2012).

BEAM is divided into two parts to assess both the construction of new buildings as well as retrofits of existing buildings. In this way, the unique considerations for developing new buildings as well as those for existing buildings can be assessed fairly. The ratings look at many aspects going into developing and maintaining buildings, from the environmental impact to effects on the cultural heritage of a site. BEAM provides a measurement system with high sustainability targets for building developers or owners. BEAM has become prevalent in the new buildings in Hong Kong with 26 having achieved platinum level, 12 gold level, 4 silver level, and 6 bronze level as of February 6, 2017 (HKGBC, 2017).

BEC has done two studies on energy-efficient technologies: *Every Building a Powerhouse* (EBP) (Close & Chau, 2010) and *Carbon Smart Buildings* (CSB) (BEC CCBF, 2012). EBP was an extensive research project published by BEC in 2010. The main goal of the project was to research the current state of Hong Kong’s building technologies and analyze the costs and benefits of installing existing and emerging technologies with the potential to conserve, store, and generate energy. These technologies, some of which are shown in Table 2.1, include simple improvements such as replacing incandescent bulbs with compact fluorescent lamps (CFLs) to more novel approaches such as placing quiet revolution (QR) wind turbines on buildings to generate electricity. The report researched 29 different technologies and calculated the return on investment; only two of the 29 technologies required more than five years to have a net positive return on investment (ROI) (Close & Chau, 2010).

Table 2.1: Sample of Energy-Saving Technologies from *Every Building a Powerhouse* (Close & Chau, 2010)

Technology	Description
Solar Air Conditioning	Solar power is used to mitigate the amount of energy used.
Smart Meters	Use of electronic meters to monitor energy use and reduce waste
LED Lighting	Light emitting diodes that provide the same amount of light as fluorescent bulbs using less energy
Lifts	Linear Synchronous Motor (LSM) is an improved elevator system which takes less space and energy

The CSB project used data from the EBP project and other BEC projects to run computer simulations to determine the effectiveness of these technologies when refurbishing a standard office building. Highly accurate data were obtained by taking into account the dimensional area in the building, the placement of the technologies and other relevant factors. The simulations were tested on selected Hong Kong buildings and the payback periods for these green technologies were shown to be much shorter than estimated in EBP. In practice, the payback period on these technologies averaged only 3 years (BEC CCBF, 2012). These findings were used to inform landlords on practical investments that would increase energy performance in their buildings, and to enable tenants to negotiate for a greener office space. For example, the three technologies in Table 2.2 could save as much as a third of the total energy consumption of the building and pay back their investment in as little as 3 years. According to a BEC employee, despite its success at providing relevant data, CSB was still deemed overly conservative by representatives at BEC, with a focus on proven technologies and little leeway for innovation. Readers of the report have requested supplemental case studies to show implementation of the technologies and real world experience and successes.

Table 2.2: Technologies and their ROIs periods (BEC CCBF, 2012)

Technology	Cost	Savings (% of total building energy consumption)	Comparable Energy Savings	Payback Period (years)
Low Energy Lighting	$0-190 HKD per m^2	6%	5-40% of lighting energy vs. standard 500 lux design	0-6.5
Ultra-Efficient Air-Conditioning	$4000 HKD per 1 ton of refrigeration	18%	20-30% vs. traditional air conditioning	3
Chiller Dynamic Control	$30-60 HKD per m^2	Up to 13%	20-30% of cooling plant energy vs. water-cooled constant speed plant	0- 8

Other organizations and government agencies advocate for and conduct research on energy efficiency in Hong Kong, and influence adoption of new technologies. Hong Kong's Electrical and Mechanical Services Department (EMSD) is a government department that regulates the use of electrical and mechanical technologies. The energy efficiency Office (EEO) of EMSD further works to increase the energy efficiency of Hong Kong through issuing codes of practice and energy efficiency guidelines (EMSD, 2015). EMSD is also "actively involved in promoting energy efficiency and the protection of the environment through services and activities for our customers and the community, as well as administering Hong Kong's first energy efficiency ordinance" (EMSD, 2011/2012). EMSD has also produced reports on new energy-efficient technologies, including papers on energy-efficient technologies in the areas of lighting, air conditioning, and more (EMSD, 2016l). These reports use case studies to conduct research on the various technologies, providing valuable data on the operating outputs of devices in a realistic setting.

2.3 Motivations and Deterrents to the Uptake of Sustainable Technologies

BEC's *Every Building a Powerhouse* report identified multiple energy saving technologies with payback periods of less than 3 years (Close & Chau, 2010). With such savings, one would imagine that all businesses would adopt these technologies but this is not the case.

This subsection explains why businesses may choose not to adopt new energy-efficient technologies and summarizes the barriers to their adoption.

Like New York and London, Hong Kong is a financial center and is home to a cluster of nationally and internationally significant institutions such as stock exchanges, banks, and investment managers. In addition to these major corporations, Hong Kong also includes many small to medium sized enterprises (SMEs) ranging from restaurants to markets. Typically, the highest priority of businesses in Hong Kong is to create a profit, and not all businesses have energy efficiency in mind as an important goal. This leads to the use of inexpensive but less efficient technology in many commercial buildings in Hong Kong (Lee, 2009).

One of the greatest barriers to the uptake of energy-efficient technologies is that many people do not have the necessary information to make informed choices between technologies. Building managers and landlords are always interested in minimizing risks and costs when deciding which technologies to use during retrofits. Without information to show that these risks are minimal, some landlords choose to retrofit using familiar technologies, and avoid investing in more energy-efficient devices. As a result, buildings are equipped with outdated and less energy-efficient technology.

A study of Hong Kong's business sector shows that incentives for improving technology differ based on company size. A major incentive for larger companies to improve the energy efficiency of their buildings is to improve the reputation of the company. Many businesses have advertised themselves as energy-efficient to enhance their brand image (Hong Kong Environmental Industry Association, 2014). Companies also improve energy efficiency to obtain a higher BEAM certification, which can be a good advertisement for the building and enhances portfolios for development groups. Conversely, the main incentive for SMEs is to gain a competitive advantage over other companies. Therefore, increasing energy efficiency would only be of interest to them if it would lead to an increase in company revenue (Studer, Welford & Hills, 2006).

About 70% of all buildings in Hong Kong are commercial buildings (Hong Kong Housing Authority, 2016). In most buildings, tenants are not responsible for making changes to technology in the building. Changes are primarily made by landlords, which means implementation of energy-efficient technology will happen only if the landlord wishes to do so. An additional issue is that both the tenants and the landlord must agree on both the timing of and party responsible for paying for the retrofits. For situations where tenants are responsible for retrofitting, the major barrier is that the tenant may only be leasing that location for a certain period of time. As a result, the tenant may not receive all the benefits of the retrofits and therefore would have less incentive to install them. On the other hand, the landlord does not always pay for the energy use of that property and as a result, may think that any benefits of retrofits will only be gained by the tenant. Hence, there is no reason for the landlord to spend more on energy-efficient upgrades when retrofitting the property.

While rented properties do have certain barriers, green leases are intended to overcome them. Because the expectation is that a green building is designed, constructed and operated to achieve sustainability, water efficiency, energy, resources and indoor environment quality goals, a green lease addresses the responsibilities of the landlord and the tenant in these areas. With a green lease, the technology used will be more energy-efficient, making this one possible solution for rental properties (Green Building Council Australia, 2015).

In some cases, the tenant pays a specific monthly amount to the landlord, which includes the cost of utilities and electricity. In such situations, the landlord could retrofit the property to have a lower electric bill. Thus, the landlord has an incentive to retrofit the property with technology that is more energy-efficient.

Another barrier to implementing more energy-efficient technology for small-and medium-sized businesses in Hong Kong is the lack of government requirements. A majority of businesses have stated that a lack of legal requirement is the reason for not installing energy-efficient technology. Therefore, establishing a requirement from the government would be a very useful solution to improve the state of technology being used (Studer, Welford, & Hills, 2006).

Currently, BEC is working on a project similar to CSB to increase energy efficiency in commercial buildings. The research conducted in this WPI student project will contribute to the larger BEC project where BEC will research the economics of energy efficiency using simulations to predict the payback periods of various technologies. The team's project will provide data from interviews and questionnaires to assess the uptake of new energy-efficient technologies and obtain reasons why people do or do not use them in their buildings. The team will follow the procedures and techniques described in the methodology section below to collect these data.

3 Methods

The overall goal of this project was to identify, analyze, and evaluate new technologies in building lighting and mechanical systems that can reduce energy usage and costs in commercial buildings in Hong Kong, and identify barriers and benefits to the widespread adoption of such technologies. This section discusses how the team fulfilled each of its four main objectives:

Objective 1: Create a list of technologies that can improve the energy efficiency of buildings in Hong Kong.

Objective 2: Provide descriptions, data, and analysis on each technology within the list.

Objective 3: Identify the barriers and benefits to the adoption of new energy-efficient technology in Hong Kong.

Objective 4: Compile a series of case studies on technologies within the list to support the findings.

3.1 Interview Methods

The team used interviews to obtain data and opinions on the energy-efficient technologies used in Hong Kong's commercial buildings as well as the barriers and benefits to adopting new technologies.

3.1.1 Selection of Interviewees

Potential interviewees were selected because of their experience and expertise with energy-efficient technologies and their use in Hong Kong buildings. The initial group of interviewees was selected from the list of BEC members and advisory council members. The team reviewed the list and selected professionals who fit within one or more of the five professional categories: technology supply, hotel management, property development, property management, and energy advisory consulting. Interviewees from each category provided the team with unique perspectives on different technologies and the process of large-scale adoption. Additional people in the same categories were selected by the liaisons at BEC, Maya de Souza and Jonathan Ho. They sent out the initial invitations to increase the response rate. Each interviewee and company was assigned an anonymous name, using "Interviewee 01" to "Interviewee 21" and "Company A" to "Company R," to protect the identities and views of the individuals as well as the companies they represent (Appendix C).

3.1.2 Interview Protocol

The interviews all followed a base script (Appendix A.2) and were 20 to 90 minutes in length. The interviews were primarily conducted by two students, to avoid overwhelming the interviewee, with one as the interviewer and the other as the scribe. The whole team did attend a few interviews, either because they were requested to do so or because the interview was informational for the whole team. In these interviews two students asked questions and two took notes. The interviews were audiotaped, if the interviewee gave permission, to supplement the notes taken by the scribe.

The interviewer opened the interview with an introductory description of the BEC and WPI portions of the project as well as a disclaimer. The team described what they already knew about the interviewee and his/her company, and began each interview by asking if any information had been left out, to ensure that the team had a clear understanding of the interviewee and company before beginning questions. The interviews were semi-structured, using a predetermined set of questions, while allowing the interview to flow as a conversation. The interview questions (Appendix A.3) focused on qualitative aspects, while more detailed and data-specific questions on different technologies were included in a post-interview questionnaire (Appendix B). This detailed information was not readily available at the time of the interview because the interviewee often required input from another person who had the specific data available to them. The interviewer reviewed the questionnaire to clarify any questions as well as get the interviewee thinking about colleagues who were more suited to answer. This process established a sense of trust and familiarity between the interviewee and the team, in order to maximize the response rate for the questionnaire. Following the interviewee's response, the interviewer recapped the information and asked if the interviewee had any additional comments.

3.1.3 Interview Analysis

There are multiple approaches to analyze qualitative data. The team used a *directed content analysis* approach to analyze the responses collected from the interviews. Directed content analysis uses prior research or theories to identify key concepts to focus on for the initial code categories (Hsieh & Shannon, 2005). The next step is to highlight the text from interview transcripts that fits in the initial categories. The broad categories for the initial sorting of data were barriers to adoption, benefits of and incentives for adoption, information about specific technologies, and other miscellaneous but useful information that did not fit in the previous categories. These broad categories enabled the team to identify relevant trends specific to each objective.

3.2 Compile a List of Technologies

The team identified 22 energy-efficient technologies in lighting, cooling, lift, and escalator systems for use in commercial buildings in Hong Kong . The team narrowed down the list to 14 technologies that were viable to decrease the electricity usage in existing commercial buildings, by assessing the advantages and disadvantages of each technology using data collected through desk-based research, interviews, and post interview questionnaires.

3.2.1 Preliminary Identification of Technologies

A preliminary list of technologies was compiled primarily from two past BEC projects: *Carbon Smart Buildings* (CSB) and *Every Building a Powerhouse* (EBP), and supplemented with reports from Hong Kong's Electrical and Mechanical Services Department (EMSD). These reports provided information on commonly used technologies in Hong Kong.

On January 13, 2017, the team attended the first workshop for the BEC project with which this IQP is associated: *The Economics of Energy Efficiency in the Built Environment – Developing the tools for making decisions on cost-effective solutions*. The workshop was attended by members of the BEC Energy Advisory Group (BEC Energy AG), which is responsible for acting as advisors to the BEC board and membership on matters related to energy management. The team presented a preliminary list of technologies and interview questions for the Advisory Group to discuss. The group provided input on the scope of the technologies, gave advice if these technologies were already commonly used and if they were the right ones to explore in the context of Hong Kong, as well as suggestions of additional technologies to research and additional sources for information. These suggested technologies were further researched to evaluate whether or not they were viable and within the scope of the project. The list was updated with further background research to create a comprehensive list to use as a reference during the interviews.

3.2.2 Stakeholders' Experiences with the Technologies

Interview questions focused both on which technologies on the team's list the interviewee knew about and possibly had experience with as well as which ones they had either not heard of or not considered. These questions helped to identify the commonly known and used technologies as well as gauge the interviewees' familiarity with the different technologies. The team developed a general script of interview questions (Appendix A.3). Questions for building managers and developers asked about technologies they currently use in their buildings and how successful they have been. Questions for energy advisory companies focused on the technologies they recommend to clients and have been implemented successfully. The technology supplier questions focused on the specific technologies the company developed and/or supplies.

The post interview questionnaires enabled the team to gather more detailed data on specific technologies (Appendix B). The questionnaires asked about technologies used, developed, or recommended by the company. By asking the building developers, owners, and managers if they were familiar with each technology, the team was able to assess which technologies were not commonly known in order to focus on providing useful information about new technologies rather than ones that were already common practice. The questionnaires from the technology developers provided sample data on the quantitative factors of each technology to assist with the analysis of energy and monetary costs, and savings. The questionnaire for the energy advisory consultants gathered information on the technologies they specifically recommended to clients to assist in choosing the technologies that would be practical for use in Hong Kong's existing buildings.

3.2.3 Identifying Preferred Technologies

The team gathered all of the data about the preliminary list of technologies and developed four criteria to select those that would be most suitable for use in Hong Kong. These criteria were developed based on initial desk research, discussion with the sponsor liaisons, and feedback from interviewees. The first criterion was that the barriers to implementing a technology should not outweigh its benefits. This primarily meant that the technology was cost-effective with a reasonable payback (generally under 5 years to stay within a company's lease period) and was relatively easy to install during a routine retrofit. The second criterion was that the technology must be suitable for implementation in existing buildings in Hong Kong. The technology must take into account the terrain and densely populated layout of Hong Kong as well as the humid and warm year round climate. The technology must either be compatible with current building systems or have the ability to be included in a retrofit. The third criterion was that the technology had to be relatively new, or at least not widespread throughout the city. This was to avoid sharing common knowledge information, focus on educating building managers and owners about new technologies, and provide a new perspective on increasing energy efficiency in Hong Kong. The final criterion was that the technologies must fit within the scope of electricity saving technologies to be used in existing commercial buildings.

3.3: Create a Description of Technologies

The team compiled additional information on each technology within the list of preferred technologies. This information included an overall description of each technology with specific data, its advantages and disadvantages, and information on the retrofit process. These data were collected through desk-based research, interviews, and post interview questionnaires to have a combination of data from technology developers as well as actual implementations. The data and discussions found in the WPI student project will be used by BEC in its larger project.

3.3.1 Interviews

Interviewees were asked to provide general descriptions for each of the technologies, and to explain some of the advantages and disadvantages of each. Because these descriptions would be used to influence the decisions of building managers, owners, and developers, the same information was requested from each type of professional. For example, each interview contained questions asking what technologies the interviewee recommended and why, in order to build on the team's understanding of the technologies within the list. Specific technologies frequently came up throughout the interviews, especially during questions regarding the overall advantages and disadvantages to retrofitting, and at the beginning of each interview when asking the interviewee to elaborate on their experiences with their company. Whenever a technology was mentioned throughout the interview, the team asked the interviewees to elaborate on it as much as possible, then included this information in their notes to review following the interview.

3.3.2 Post Interview Questionnaires

Questionnaires were used to collect more quantitative data such as the capital cost, the payback period, and operational savings. These data were particularly important when evaluating the individual technologies, as cost was a primary factor noted by developers/managers/owners when deciding for or against a retrofit or installing a specific technology. Data pertaining to the actual usage of the technologies allowed the team to assess which of the newer technologies are realistic to suggest for use in Hong Kong.

3.3.3 Desk-Based Research

After conducting the interviews, the team conducted desk-based research to supplement the data collected from the interviews and questionnaires. Further sources were included, and any numerical data cited by interviewees was backed up by further documentation from general sources, including EMSD, CSB, and EBP, as well as other sources specific to individual technologies.

3.4 Identify Benefits and Barriers to Adoption

The team analyzed the qualitative and quantitative factors that would impact the uptake of these technologies on a larger scale. This analysis was important when determining whether or not certain technologies were practical to recommend as well as understanding how to best provide information to facilitate uptake of energy-saving technologies in general. The team focused on understanding the reasons why building managers and owners do or do not upgrade to improve the energy efficiency of their buildings.

The interviews provided opinions about energy-efficient technologies from a variety of professionals. These experts had varying perspectives on reasons why new technologies were or were not being implemented. They provided insight on what factors the building owners and managers consider when deciding to retrofit a building and selecting the technologies to update. When analyzing the interviews, the team sorted the responses into categories, including positive and negative views on each technology, reasons for or against retrofitting buildings, barriers that people have experienced when working to increase a building's energy efficiency, and benefits observed after implementing new technologies. The information was used to narrow down the list of technologies and gain an understanding of what barriers need to be addressed to maximize the uptake of the recommended technologies. When the interviewees mentioned statistics that corresponded to a barrier, the team searched for sources to use to backup the interviewee and supplement the overall barriers discussed in interviews.

3.5 Compile Case Studies

The team collected information about retrofits and technology upgrades from interviewees to create case studies that could supplement manufacturers' data as well as opinions expressed in interviews. The interviewees were asked to recall their specific experiences with retrofitting buildings to be more energy-efficient. These studies looked at barriers that were encountered when installing the technologies, how they were overcome, and the benefits gained. The case studies can be used as an example for others needing a more tangible description of the use of the technology to complement manufacturers' data.

4 Findings

The following section discusses the information collected through desk-based research, interviews, questionnaires, and case studies. It includes information about specific technologies in order to narrow down the list of technologies to recommend and elaborates on the technical descriptions as well as advantages and disadvantages required for objectives 1 and 2. Information about barriers to the overall uptake of energy-efficient technologies came primarily from interviews and fulfilled objective 3. Objective 4 comprised the collection of case studies.

The research methods had mixed success. Only one third of the potential interviewees responded to the invitation and followed through with an interview. This low rate is attributed to the short time frame the team had to conduct interviews as well as the Lunar New Year holiday occurring in the middle of this time period. A total of 16 interviews were conducted with representatives from 3 companies that own, manage, and develop properties; 1 hotel building owner; 3 building managers; 3 energy advisory consultants; and 6 technology suppliers/developers (interview notes are in Appendix C). In contrast, the questionnaires were sent to 12 of the interviewees and had an 75% response rate (9 questionnaires returned). This high response rate is because questionnaires were sent to interviewees who were more invested in the project. They had already taken the initiative to participate in the interview, had personal contact with the students, and had discussed the questionnaire during the interview. The team compiled 24 case studies with information for 12 provided by interviewees, 4 by BEC, and the remaining 8 from EMSD.

4.1 Technologies and their Advantages and Disadvantages

Buildings in Hong Kong, while varied in structure and use, all require lighting, air conditioning, and lifts and/or escalators. These systems consume the majority of electrical energy in commercial buildings and present a large potential for energy savings. This section discusses which technologies are currently used in Hong Kong. The researched technologies are divided into the three categories of lighting, air conditioning, and lifts and escalators.

4.1.1 Baseline of Technologies Used in Hong Kong

One component of this project was to understand the current baseline of usage for relevant technologies in Hong Kong. Knowledge about which technologies are currently being used, as well as which technologies are not, is important to the larger BEC project, for both the development of the recommended technology list as well as identifying which technologies are well known and will likely need less information provided, and which lesser-known technologies will be important to promote. The team planned to use the questionnaires to establish this baseline, but ultimately did not have enough responses to do so. An additional problem with using the questionnaires to establish a baseline was that the technology list on the questionnaire was updated in the middle of the interview process to include technologies that were discussed in earlier interviews. Although the data from the interviews and questionnaires were not enough to establish a baseline of technology uptake in Hong Kong, the team was still able to gather the initial information that BEC can build on to establish a baseline.

The most important questionnaire was the one sent to property developers, managers, and owners. However, only one questionnaire was returned from this category of interviewees (Appendix C.4). While informative, these data were provided by a company that is especially focused on sustainability and is not representative of most property developers, managers, and owners in Hong Kong.

The questionnaires from energy advisory consultants had a higher number of responses, with 4 questionnaires returned, and gave insight on what technologies are currently being recommended in Hong Kong. The options for each technology listed were “often recommended,” “sometimes recommended,” “never recommended,” and “unfamiliar with.” Chilled beams were the only technology that had a consensus of “never recommended”. No technology was “often” recommended by all of the consultants. The only technologies recommended either “often” or “sometimes” by all four consultants were LEDs, air source heat pumps, and natural lighting controls (daylight sensors). Technologies that were recommended either “sometimes” or “often” by three consultants, where the fourth consultant abstained, were variable speed air conditioning, variable flow control for condensing water pipes, varying fans and motors, controls and smart meters, and regenerative braking. The responses from these questionnaires were mixed and, due to the small sample, could not be used to make a conclusion on actual usage.

Another source of information for the baseline was the interviews, where technologies were mentioned as being used or recommended by the interviewees and their companies. The most common technologies mentioned in 11 of 16 interviews were smart controls and meters. Both LEDs and occupancy sensors were mentioned in 8 interviews as being used or recommended. Within the category of air conditioning, oil-free chillers were discussed in 6 interviews while variable speed chillers and heat pumps were discussed in 4 interviews.

The data from the interviews and questionnaires are insufficient to establish a baseline of technology usage in Hong Kong; however, the most commonly discussed and recommended technologies were LEDs, smart controls and meters, occupancy sensors, and variable speed devices.

4.1.2 Lighting

Lighting is often the first system businesses target to lower energy use in their buildings because of the perceived lower cost, easier installation, and shorter payback period when compared to those of other systems (Interviewee 03). The main lighting designs and technologies studied were LEDs, T5 fluorescent lamps, and task lighting design. While many people are aware of these technologies, they are still hesitant to use them. These technologies have not been implemented widely enough throughout the city, and as a result, there is potential for further improvement in Hong Kong's energy efficiency through the installation of improved lighting systems (Interviewee 19).

LEDs are one of the most well known energy-efficient technologies. They have a payback period of less than 2 years and a usage lifespan of 50,000 hours compared to the 20,000 hour lifespan of T5 fluorescent lighting fixtures (Interviewee 08) and, as a result, interviewees prefer LEDs over T5s (Interviewee 03, 06, 08). The energy efficiency of LEDs is still being improved while T5s have shown no signs of improvement and are outdated (Interviewee 08). T8 and T5 fluorescent lights are commonly used in existing buildings of Hong Kong and, as a result, building owners and managers often choose to keep the same type of technology rather than retrofit the fixtures to use LED lighting (Interviewee 02). A barrier to installing LEDs is that installation cost and difficulty of retrofitting a fluorescent fixture for LEDs depends on the type of LED tube used. Certain LEDs can be directly installed into T8 fluorescent lighting fixtures. However, these LEDs are not as energy-efficient as the LEDs used in fixtures designed specifically for LEDs. More sophisticated control systems can also be used in conjunction with LEDs to increase the savings further, but may require rewiring in addition to the installation of new fixtures. To maximize the energy saving from LED tubes, the fixture and wiring both need to be replaced, leading to more expensive installation costs (Premier Lighting, 2015).

Even though T5 fluorescent lights are not as energy-efficient as LEDs, building managers may choose them because replacement is simple and T5 lamps are still 30% to 40% more efficient than T8 lamps (EMSD, 2016b). T5s are also only 0.625 inches in diameter, compared to the 1-inch diameter of T8s. This smaller size provides T5s with greater flexibility for fluorescent lighting designs (Close and Chau, 2010). While the cost of a T5 lamp may be around 15% more than T8s, this higher initial cost is compensated by T5's higher energy efficiency (EMSD, 2016b). For companies who wish to improve energy efficiency of their buildings without having to retrofit the wiring of the lighting system, T5s are currently the best replacement to T8s.

However, LEDs are still more energy efficient, and do not require any additional costs to dispose of properly. (Premier Lighting, 2015).

In addition to these two lighting technologies, the lighting design is also an essential part of improving energy efficiency of a building. Task lighting is a design practice in which the number of lights being used in a room is limited to the required amount of light in the room. According to computer simulations run by EMSD, using a task lighting design reduces the number of light fixtures required and can lower the energy usage from lighting fixtures in an open plan office by 22-31%, depending on the spaciousness of the workspaces (Appendix F.17, F.18) (EMSD, 2016d). Offices are often too bright and task lighting mitigates this problem (Interviewee 02). Another advantage of task lighting design is that the installation cost is also reduced since fewer lighting fixtures are required. However, a major barrier to the implementation of task lighting is the lack of consumer awareness. Interviewee 16 said that, when asking for a lighting design for their office building, the company was given a design that placed lights at certain intervals of ceiling tiles rather than by looking at the user's needs. Clients who do not know about lighting design practices, specifically task lighting, will most likely accept an inefficient design (Interviewee 16).

4.1.3 Air Conditioning

Because of Hong Kong's tropical climate, air conditioning is used year round. Large amounts of energy are used to dehumidify and lower the temperature of the hot, humid outside air to a comfortable indoor temperature. This section discusses all aspects of the air treatment and cooling systems within commercial buildings that comprise 31% of Hong Kong's electricity consumption by end use in the commercial sector (EMSD, 2016k). Oil-free chillers, variable speed capabilities in the motors and pumps used by air conditioners and fluid circulation systems, and electronically commutated plug fans are all technologies that can reduce energy in the cooling of the building. Heat pumps work to enhance the efficiency of the overall air conditioning system through reducing wasted energy.

Standard air conditioning units maintain room temperature at a certain desired temperature using feedback controls from the room thermostat, which uses fixed temperature set points to turn the fans or the chiller on and off.. This fluctuating pattern not only is uncomfortable for the occupants, but wastes energy (EMSD, 2016e). Variable speed air conditioners (VSD) have the ability to lower their fan speed once the desired temperature has been reached to maintain the temperature with no fluctuation. At full load, the energy savings of VSD chillers is not significantly greater than traditional units, but the ability to vary speed is useful during periods of low load in Hong Kong such as the winter season, accumulating savings over time (Interviewee 03).

Compressors in traditional air conditioners require oil to lubricate the moving parts. Oil-free chillers use magnets to levitate these parts and thus remove the need for a lubricant while reducing energy losses due to friction. The removal of oil lowers maintenance costs for both refilling lubricant and replacement of worn parts. This device functions best in part load conditions of around 85%, meaning there is a greater initial investment required for a larger chiller to obtain this maximum efficiency (Jackson Ball, 2016). In addition, the oil-free chiller is more expensive than a conventional air conditioner (SA Parker & J Blanchard, 2012).

Some buildings have water-cooled air conditioning systems, which use pipes to transport the coolant throughout the building from a central chiller plant. Conventional chiller plants utilize a constant flow control to guarantee the system can handle the full load of the building (EMSD, 2016f). Realistically, there are lower load conditions during the operation period of the system and variable flow control technology can lower energy use for these situations. In variable flow control, a variable speed drive (VSD) regulates the flow of the coolant through the system. The control system monitors the temperature of the water leaving the condenser and adjusts the flow rate of the water to match the demand required by the building (EMSD, 2016f).

Buildings with centralized air conditioning use fans to circulate the air from the chiller throughout the building. These fans use a large amount of energy when running at top speed, for instance, running a fan twice as fast will increase the power usage by a factor of 8 (EBN-PAPST, 2017). Variable speed drive fans, combined with sensors or advanced control systems, can run at lower speeds when the required load is lower (Interviewee 16). Maintenance costs are also reduced because the fans experience less wear and need to be replaced less often.

Using Electronically Commutated (EC) plug fans, which are brushless electric fans, further reduces energy usage (Interviewee 03). A typical alternating current (AC) fan has a metal brush inside, which drives the motor by regulating the swapping of magnetic fields. Instead of using a metal brush, an electronic device controls and drives the motor (Miller, 2010). Without a brush, there is less friction between the parts in the motor, allowing it to run 30% more efficiently than traditional AC fans. Furthermore, maintenance is not required to replace worn brushes. Also, advanced electronic motor controls are more flexible and can further reduce energy by varying the fan speed at part load situations (EBN-PAPST, 2017).

Heat pumps, while not directly part of the air conditioning system, provide enhanced efficiency to the temperature regulation of the building. Using water, heat pumps capture heat from hot air expelled from air conditioners and other appliances, and transport it to areas such as showers or water boilers (Interviewee 08). A case study done by EMSD (Appendix F.22) involved installing a heat pump into a company's building to heat the showers from the air conditioning waste heat and saved the company 290,000 kWh annually in electricity, resulting in a payback period of 5.2 years (EMSD, 2016g).

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4.1.4 Lifts and Escalators

Hong Kong is the sixth most densely populated city in the world (Demographia, 2016). Due to its limited geography and terrain, Hong Kong needs to be built up instead of out like many cities. In Hong Kong's high-rise buildings, lift and escalator use plays a much larger role than in the United States (Interviewee 13). There are currently four different energy-saving technologies that could be used in Hong Kong's vertical transportation systems: linear synchronous motors (LSM), regenerative braking, lift destination control devices, and service on demand escalators.

Linear synchronous motor (LSM) lift systems use magnetic field induction to drive the car up rather than traditional motors that operate with conventional pulley and counterweight systems. Compared to conventional systems, LSM lifts are able to move much faster, reaching speeds of over 10 meters per second (Close & Chau, 2010), and can operate with less space in hoist ways of any height (Nationwide Lifts, n.d.). However, the amount of savings from these systems is dependent on the average speed of the existing lift. Therefore, these lift systems are more cost-effective in high-rise buildings, where lifts can reach higher speeds. For example, in high-rise buildings with lift speeds of over 10 meters per second, the LSM efficiency is over 85% (Close & Chau, 2010).

Lifts with regenerative braking systems are able to recover some of the energy that would otherwise be lost from braking (EMSD, 2016h). During times when a cab is traveling up with a light load, or down with a heavy load, the system's motor acts as a generator, and actually generates more power than it uses. This excess power is returned to the facility's electrical grid for use elsewhere in the building, which allows the lift to lower its net energy usage. Over time, the power generated can add up to noticeable savings compared to conventional lifts. This technology also saves energy required by air conditioning systems to cool the lift shaft, since the energy generated by regenerative braking would have normally been lost as heat in the building (ASME, 2016).

Much like LSM lift systems, the amount of energy savings provided by regenerative braking varies based on lift speeds and traffic patterns. Specifically, regenerative braking is able to save more energy on lifts that reach higher speeds, because more energy is generated during braking. For example, according to an EMSD case study of a central government office building (Appendix F.22), savings ranged from 17% in cabs traveling at an average speed of 1.75 m/s, to 27% in cabs traveling at an average of 5 m/s (EMSD, 2016h). Therefore, these lifts are generally installed in buildings with more than ten floors, as taller buildings allow lifts to operate at a higher speed (Interviewee 08). This makes regenerative braking ideal for buildings in Hong Kong as 98% of the buildings in the city are over 12 floors tall (Emporis, 2016).

In lifts with more than one shaft, a group of control systems can be installed along with a 'destination control device' in which the passengers select their destination before entering the lift car. These systems then process the passenger destination information using advanced software to plan the trips for each lift in order optimize the flow of passengers, minimize the number of stops needed, and increase the operational efficiency of the lift system (Toshiba, n.d.). Lifts using these new destination control devices save energy by reducing the number of stops when servicing passengers, and can shorten the average wait times of a lift by 30% compared to conventional control systems (Schindler, n.d.). However, a barrier to using destination control devices is that these control systems are only able to improve lift efficiency in buildings with more than one shaft (Toshiba, n.d.).

One of the latest new technologies for escalators is the service on demand (SOD) escalator. These escalators use occupancy sensors to detect the presence of passengers. When the system is not being used, the escalator's control system can run either at low speeds, using a variable speed drive (VSD), or turn off completely. According to an EMSD case study of a government office building (Appendix F.21), the possible energy savings per escalator, which come from implementing an SOD design over a conventional one, are 52% for auto on-off control systems and 14% for auto two-speed control systems (EMSD, 2016i). However, the amount of energy savings that comes from switching to SOD escalators varies based on each escalator's traffic patterns. If an escalator spends less time servicing passengers throughout an average day, then retrofitting will likely save more energy, because the escalator will be able to spend less time operating at normal speeds once SOD control systems are implemented. SOD savings are easier to calculate in buildings such as office spaces, cinemas, theatres, public facilities, and educational institutes, due to their regular traffic patterns. In locations such as shopping malls however, the arrangement of circulation routes and the nature of retail will cause the service patterns of escalators in different areas of the mall to fluctuate over time, which makes it more difficult to calculate the savings.

The usage patterns of lifts and escalators affect the amount of energy that can be saved by switching to more efficient systems. Because energy savings are directly related to usage patterns, it is often difficult to provide any general information on the energy savings of these technologies (Interviewee 08). If a building's usage will not result in significant savings from these technologies, then the return on investment will likely take too long as well. For service on demand escalators, the payback period varies from one to three years depending on how infrequently the escalators are servicing passengers (Interviewee 08). Building owners and managers must consider the building and its usage carefully before deciding to incorporate these technologies.

4.2 Barriers to Adoption

This section discusses barriers that the team identified as deterrents to building managers and owners adopting energy saving technologies as a whole rather than disadvantages to specific technologies. The most prevalent ones are lack of information, product lifespan, compatibility, tenant and landlord relationships, and costs.

4.2.1 Lack of Information

People in Hong Kong generally know that it is important to be environmentally friendly, but they often think that the savings are minimal and do not know the proper steps to take to increase the energy efficiency of their buildings (Interviewee 10). Interviewees frequently stated the need for further information about the costs and risks of upgrading technologies to improve the energy efficiency of their buildings, wanting to know the potential savings for their particular buildings, and wanting to see successful examples.

Risk Management

Building managers and owners are often hesitant to use new technologies that have not been proven to work in Hong Kong (Interviewee 16). These companies want safe and guaranteed paybacks. Investing in new technologies is risky if the technology does not generate the anticipated energy savings. The upfront capital and installation costs of energy-efficient technologies are often higher than the cost of equivalent less energy-efficient technologies, so the *building owner* is taking a risk by investing more for an uncertain return. Installing a different technology has the potential to work differently than the existing one and requires the *building manager* or engineer to learn the proper operation and management of the new technology. *Building engineers* are also averse to risk (Interviewee 08) and may not want to learn how to manage new technologies. Properly managing and utilizing the new technology is crucial and many systems fail because the property manager or building engineer does not understand how best to operate the system (Interviewee 03). *Landlords* need to be assured that the new retrofits will not negatively impact their tenants, such as a different color temperature of light or a noisy air conditioning system. They also need to be assured that the new changes will work properly because building owners and managers care about reliability before energy efficiency (Interviewee 13). They want to know what has been done before, where it has been done, what the cost was, and what the experience was (Interviewee 08). Case studies can show successful examples to reassure them that the new technologies will provide the promised energy savings and payback as advertised by the manufacturer.

Information about Energy Usage

Many building owners and managers do not know how the energy usage is distributed throughout their buildings. A useful method that complements improving the energy efficiency of a building is the use of meters. Meters can be used to measure the amount of energy used by different devices, such as lighting, air conditioning systems, and plug loads, and can identify trends for each device’s energy use over time (Interviewee 09). These trends can be analyzed to understand which of the systems in a building are using the most energy. Building managers and landlords can use that information to make informed decisions when looking to save energy, replacing the most wasteful systems with more energy-efficient technologies (Interviewee 09).

About 10,000 companies throughout Hong Kong have been using energy meters to record the amount of energy used in their offices; however, this is less than half of the total companies currently operating in Hong Kong (Companies Registry, 2017). All companies using these meters are large businesses because energy suppliers in Hong Kong have been given approval by the Hong Kong government to install energy meters in the office space of large businesses. Having energy meters in office spaces allows energy suppliers to analyze the energy used by different units in the offices to provide the company with a detailed analysis of the energy usage of the building. This analysis enables energy suppliers to provide recommendations to companies about energy saving changes and practices they can implement. Many small and medium sized businesses have not installed energy meters and cannot obtain data on their energy usage because the government has not provided energy suppliers the approval required to install energy meters in office spaces of small and medium sized companies or residential buildings. Therefore, energy advisors are unable to provide recommendations to improve the energy efficiency of those offices (Interviewee 13).

4.2.2 Product Lifespan

Technologies all have different lifespans and this plays an important role in making decisions about when to upgrade the current system as well as choosing a specific new technology. When asked what factors they considered when deciding to do a retrofit, all of these interviewees said that the lifespan of the currently installed technology was a deciding factor. They do not see the need to replace a technology that is still operating and meeting their performance requirements. Building owners budget for and install products with the expectation that they will function reliably for a certain number of years before needing to be replaced. Another aspect of installing new technology before the end of the current product’s lifespan is the need to dispose of the existing technology. Building owners will incur additional costs earlier, especially when disposing of hazardous items such as fluorescent bulbs and cooling refrigerant, in addition to the new installation cost. New, more energy-efficient, technologies are continuously being developed, so building owners and managers will likely have even more and better choices available if they wait until the end of the current system's lifespan instead of upgrading sooner. When comparing products that either do a similar job or have a similar price, the lifespan can be the determining factor in selecting which product to purchase. A product with a longer life will often ultimately be cheaper because the user will not need to replace the technology as often.

Another aspect of product lifespan is that small and medium businesses often only make short term plans and investments and will opt for technologies that will only last for the short term (Interviewee 21). This can also be true for companies that make long term investment plans because leases are often only 3-6 years (Interviewee 02) and these companies will not want to invest in longer-lasting and more expensive technologies if they may be moving in a few years.

4.2.3 Compatibility

Buildings in Hong Kong were built at different times and have varying systems installed as well as spaces available to install new technologies. While some new technologies can simply replace the old technology and fit within the existing space and building infrastructure, many require retrofits. For example, the complexity of installing LEDs varies depending on the specific model. This can be as simple as putting a specific model of LED into an existing T8 fluorescent fixture or require new fixtures to be installed. Furthermore, if the user wants to install sensors or customize the control loops for the lighting system, they will also need to open up the ceiling and walls to replace the existing wiring. Retrofits may require analysis, testing, and redesigns of the space and systems in order to ensure that the new technology can be properly installed and used in the existing building (Interviewee 01). In some cases, it may not be apparent if a new technology will perform as expected when installed without doing site-specific analysis.

4.2.4 Tenant/Landlord Conundrum

The relationships between building owners, building managers, and tenants, are complicated. Most companies lease buildings in Hong Kong and, even if they own a building, companies often outsource the building management (Interviewee 10). As a result, it is difficult to decide who should be responsible for the planning and costs of retrofits and energy-efficient upgrades, as well as who gets the return on investment. For the purpose of this discussion, building owners and building managers are considered landlords.

Tenants are not always able to upgrade their energy using systems as many, such as lifts and central air conditioning systems, are integrated into the building as a whole, and the individual tenant is not responsible for changing those systems (Interviewee 10). The tenants can sometimes make smaller changes such as the lighting system in their units; however, with short-term leases (3 to 6 years), tenants will not want to invest if they cannot be guaranteed a payback within their lease period (Interviewee 02). In many cases, it is ultimately up to the owner of the building and, while the tenant can encourage, propose, and suggest sustainable changes, landlords may be unwilling to put in the extra money for the upgrades (Interviewee 01), especially if they do not think they will directly benefit.

Landlords do not have control over the tenants' energy usage practices and individual design of the space, especially within retail spaces (Interviewee 03) and, depending on the landlord/tenant agreement, landlords may be only responsible for the energy usage in shared spaces such as lobbies and corridors. The party responsible for paying the energy bill for individual units depends on the landlord/tenant agreement and the tenant often pays directly to the electricity company (Interviewee 10). In some arrangements, such as smaller offices where multiple tenants share an energy meter, the energy consumption is included in the rent (Interviewee 10). Landlords have the most money saving incentive to increase energy efficiency when they are paying for most or all of the energy bill.

When landlords want to increase the energy efficiency of their buildings, they must consider the roles and needs of their tenants. Retrofits may temporarily displace tenants and, even if the retrofit is conducted when the unit is unoccupied in between tenants, the construction noise of retrofits will bother tenants in other units. Energy-efficient upgrades can be scheduled to correspond with regularly scheduled retrofits and building maintenance or wait until the tenant moves out to conduct the retrofit and install the new technology (Interviewee 03) to minimize disruption.

4.2.5 Costs

Cost is a driver to deciding whether or not to upgrade technologies and was a recurring factor mentioned in interviews. Costs that impact the decision to purchase a product include the capital, installation, operation, and maintenance costs. The installation cost is the primary consideration (Interviewee 09) and, for existing buildings, this often includes the additional cost to retrofit. The building manager and owner need to be willing to invest upfront to save costs in the long run (Interviewee 17), but they will often focus on the lowest upfront cost and choose the cheapest technology available, even if the technology has lower energy efficiency or a shorter lifespan than competing products (Interviewee 09). Building owners and managers, as well as tenants, want to know the payback of the technology and usually look for paybacks of less than 5 years (Interviewee 18). This is especially important to tenants given that leases are usually 3-6 years (Interviewee 02) and they want to get their return on investment before moving.

An additional cost-related factor is that the cost of electricity is low in comparison to the total rental cost of a space (Interviewee 07). This can influence perceptions about the value of reduced operational costs with a new technology. Rent is extremely high in Hong Kong with the average monthly rent per square meter of an office in the Central district of Hong Kong being HK$592-1,033 (US$77-133) in 2015 (Hong Kong Census and Statistics Department [C&SD], 2015). For residential spaces, the utility cost is less than 1% of the total rent (Expatistan, 2017) and this can be assumed to be a similarly small percentage for office space.

4.3 Benefits of Incorporating Energy-Efficient Technologies

While the barriers to adoption are important, it is also important to consider the benefits to adoption as well when looking to increase the uptake of technology. The team identified two main benefits for property owners and managers to incorporating energy-efficient technologies into their buildings in Hong Kong: long term paybacks and good corporate image.

4.3.1 Long-term Cost Savings

The most common goal businesses have in mind when incorporating energy-efficient technology is to lower their overall energy costs and save them money long term. Property owners and property managers frequently inquire about the payback period of new technologies, because a good payback period will allow them to get a fast return on investment, and begin saving money much sooner after investing. In rented properties, a good payback period generally falls within three to six years, so that tenants can get the return on investment before their lease period ends (Interviewee 08).

4.3.2 Improved Corporate Image

Corporate image is a high priority within many companies. The corporate image is the manner in which a corporation, firm or business is perceived by the public, such as customers and investors as well as employees. One of the major reasons for customers to choose a particular product or service provider over another is because of the company's corporate image. A good corporate image can help a company increase their revenue since they will be preferred over other lesser-known companies.

The corporate image can be influenced by the technology used by the company. If a company uses energy-efficient technology for their properties, showcasing these features helps to improve their corporate image. Achieving a high BEAM rating in existing buildings often requires retrofitting. When the company receives a high BEAM certification, they can use this certification to enhance the corporate profile (Interviewee 02).

4.4 Other Considerations

While researching and recommending energy saving technologies was the primary focus of this project, it is important to note that upgrading technology is not the only way to increase the energy efficiency of buildings. Retrocommissioning is a process in which the performance of building systems is evaluated to ensure that they are operating best to support the current occupant's needs (Morton, 2013). Retrocommissioning results in solutions to adjust the current systems to solve issues such as "inefficient thermal distribution layout, miscalibrated or otherwise malfunctioning energy management controls and sensors, defeated efficiency features (e.g., variable speed drives locked at full speed), leaky air-distribution systems, inappropriate set points and control sequences, and oversized equipment" (Mills, 2012). By focusing on the management and usage of the current system, the building manager or owner can often reduce energy consumption by 5-10% and get a return on investment within 1-2 years (Interviewee 08). This simple solution demonstrates that the *type* of technology used is not the only factor that can make a building energy-efficient. It is just as important to consider how that technology should be *used* when looking to maximize the energy savings. Many technologies do not work efficiently because people are not using them effectively (Interviewee 19). For example, if a building has an energy-saving chiller but the system controls are not properly set, it will not be as energy-efficient as it could be (Interviewee 18).

Another factor to consider is behavior. Lights and air conditioning are often left on unnecessarily when the room is unoccupied. Any light that is off, regardless of type and energy efficiency, saves more energy than even the most energy-efficient light when it is on. Changing human behavior is difficult, but it is an important factor to consider, and was mentioned in over half of the interviews. Sensors and meters can be used to manage the energy usage and the data from them can educate the occupants about how much energy they are using. Control systems with occupancy sensors can turn off lighting and cooling systems when the room is unoccupied, and energy usage meters can track the energy usage to inform users where the most energy is being used, potentially motivating them to change habits. While occupancy sensors can be helpful, a behavior change can be more beneficial. For example, the occupancy sensor in a conference room in Interviewee 10's office has a timer to turn the lights off after 30 minutes of inactivity. Unfortunately, the gaps of time between use are often less than 30 minutes and the lights remain on all the time when they could be manually turned off between use (Interviewee 10). Energy-efficient technologies have high potential to save electricity, but must be supplemented with proper usage and management of the systems.

4.5 Case Studies

Case studies provide tangible and real world information about specific technologies currently being used in Hong Kong. In addition, case studies can be used to simplify complex information to make it easier for stakeholders to understand the usefulness of certain energy-efficient technologies. The team compiled a total of 24 case studies. Each case study provides different levels of information because the interviewees and EMSD sources did not always provide all of the necessary information, such as the payback period or the initial energy usage. Company representatives did not provide information because it was proprietary or the representative did not have access to it. Due to this lack of information, certain case studies are less useful because the limited information may not fully convince readers of the usefulness of the technology mentioned.

In the 24 case studies, 8 case studies included information about lighting systems including retrofits such as using LEDs, occupancy sensors, daylight sensors as well as implementing task lighting design. Case study F.2 shows that daylight sensors can be used to reduce the energy consumed by the lighting systems by 30%. Even with the high percentage of energy savings, the payback period for this technology is 13 years (BEC, 2016c). Case study F.3 shows that occupancy sensors reduced the lighting system's energy consumption in washrooms by almost 30%. The payback period of this project is 15.1 years. The greatest energy savings from changes in lighting systems occurs when older lighting technologies are replaced with more energy-efficient technology such as LEDs. Case studies F.5 show that LEDs have an energy saving potential ranging from 57% compared to T8 fluorescent light bulbs that have an input power of 72 Watts. Due to this high saving potential, the payback period of LEDs is about 3.6 years.

Eleven of the case studies included air conditioning upgrades. A majority of these case studies involved the installation of oil-free chillers. The payback period for the entire cost of the oil-free chiller provided in case study F.4 is 24.2 years, which clients may consider to be longer than they wish. However, the payback period for this chiller is so long because only one chiller out of two was replaced with the oil-free chiller. If both chillers had been replaced, the payback period for the chiller would reduce to about 18 years. When a chiller reaches the end of its lifespan it can be replaced by either a conventional chiller or an energy-efficient chiller. The price of an oil-free chiller is about $1.4 million HKD while the price of a conventional chiller is about $1.0 million HKD. With annual savings of about $60,000 HKD, the payback for the additional $0.4 million HKD is less than 7 years and the payback for the remaining $1 million HKD with efficient oil-free chillers is also shorter than that of conventional chillers (BEC, 2016b). As a result, the implementation of energy-efficient technology such as oil-free chillers is a better option when compared to other conventional chillers.

There was only one case study from the EMSD that evaluated lifts. Case study F.20 provides information about energy savings from regenerative lifts. Regenerative lifts were installed in a 23-storey office building and designed to achieve flexibility services where certain elevators will operate only for low (1/F to 14/F) floors, and high zones (1/F, 14/F to 23/F) of the east and west wings respectively. Depending on the lift speed, the energy savings were measured as 17% to 27% when compared to conventional lifts. Depending on the location and the zone of the lift, the energy consumption ranged from 2,505 kWh to 45,913 kWh and the energy recovered ranged from 565 kWh to 15,847 kWh. This shows that the consumption of energy depends highly on the location, traffic patterns, and lift speed. The case report did not disclose initial cost or the payback period. Hence, an accurate comparison with conventional lift systems cannot be made.

Only one case study, from EMSD, evaluated escalators. Case study F.21 provides information on simulations conducted on SOD escalators. Installing an automatic system to turn the escalator off after a certain period of inactivity can save 3,400 kWh per year per escalator according to the simulation. In addition, installing an automatic two-speed system in the escalator to change the speed of the escalator depending on the number of people using it can save 2,040 kWh per year per escalator. It must be noted that this was a simulation, not an actual installation. Calculating the idling time involved making some assumptions about the usage patterns of the occupants that may not be true in practice. As a result, the energy savings can be different from the values calculated from this simulation. Unfortunately, the simulation did not provide the payback period or the energy consumed and so, this technology could not be compared with conventional escalators.

5 Conclusions

The overall goal of this project was to identify, analyze, and evaluate new technologies in building lighting and mechanical systems that can reduce energy usage and costs in commercial buildings in Hong Kong as well as identify the overall barriers and benefits to the widespread adopting of such technologies. This section summarizes the technologies, barriers, and benefits identified through this project.

Recommended Technologies

The team created a list of 22 energy saving technologies and then narrowed down the list to 14 technologies using four criteria. The first criterion is that the barriers to implementing a technology should not outweigh its benefits. In most cases, this means that the investment has to be cost-effective, (generally with an ROI of 5 years or less). The second criterion is that the technology has to be suitable to Hong Kong's terrain, climate, and culture. The third criterion is that the technology has to be new, or less widely used throughout the city. By focusing mainly on less common technologies, the report can spread new information to the businesses of Hong Kong rather than repeating known information. The final criterion is that they fit in the scope of electricity saving technologies to be used in existing commercial buildings. Table 5.1 contains the 14 technologies that best met these criteria. The detailed descriptions of these technologies are in Appendix E. BEC can use this list in their larger project following this IQP, which will be provided to building managers as a tool to increase the energy efficiency of their commercial buildings in Hong Kong.

Table 5.1 Recommended Technologies

<table>
<tr><td colspan="12">Lighting</td></tr>
<tr><td colspan="3">LED lights</td><td colspan="3">T5 fluorescent lights</td><td colspan="3">Room occupancy sensors</td><td colspan="3">Task lighting design</td></tr>
<tr><td colspan="12">Air Conditioning</td></tr>
<tr><td colspan="2">Oil-free chillers</td><td colspan="2">Variable speed drive (VSD air conditioning</td><td colspan="2">Variable flow control for condensing water pipes</td><td colspan="2">Heat pumps</td><td colspan="2">Variable speed drive (VSD) fans and motors</td><td colspan="2">Electronically commutated (EC) plug fans</td></tr>
<tr><td colspan="12">Lifts and Escalators</td></tr>
<tr><td colspan="3">Linear synchronous motor (LSM) lifts</td><td colspan="3">Regenerative braking lifts</td><td colspan="3">Lift destination control devices</td><td colspan="3">Service on demand (SOD) escalators</td></tr>
</table>

Barriers

The primary barriers the team identified to the adoption of energy-efficient technologies in commercial buildings are lack of information, product lifespan, product compatibility, tenant and landlord relationships, and costs. The decision makers experiencing these barriers include building owners and managers as well as tenants. In general, building managers and owners are aware that they should make changes to increase the energy efficiency of their buildings, but they are *unfamiliar with all of the resources* available to them and are often *unsure of the savings* that can be achieved in their specific buildings. These barriers can be addressed by using data from energy monitoring meters to determine the current energy usage in a specific building to calculate the potential savings, providing information on what technologies can be used in retrofits, and providing case studies on projects that feature successful retrofits. The *lifespan* of products is an important barrier because building owners and managers frequently do not want to retrofit systems that have not yet reached the end of their lifespan. In existing buildings, the *compatibility* of a new technology with the existing building systems is especially important, and most energy-efficient updates will require a retrofit. Retrofits are difficult to schedule considering that most buildings are leased out and the tenant must be considered. Additionally, the *tenant and landlord arrangement* makes the issue of who will initiate and pay for the retrofits more complex and frequently a barrier. *Cost* is a general barrier because the upfront costs (installation, capital, and retrofit) for energy saving technologies are often more than the upfront costs for the less energy-efficient equivalent technologies.

Benefits

While there are multiple barriers to the adoption of energy-efficient technology, there are benefits as well. Important benefits are the long-term cost savings and the improved corporate image. Although the cost of adopting energy-efficient technologies is higher than that of conventional technologies, this can be recouped from the long-term energy saved. A good payback period enables the consumer to receive a quick return on investment and further save money from future energy savings. Companies can improve their corporate image by implementing energy-efficient technologies in their properties, which in turn can help the company increase their revenue as they may be preferred over other lesser-known companies, and by customers who value sustainability.

Other Considerations

A common point that came up during the interviews was that technology is not the only approach to achieve energy savings. There are other energy saving practices that stakeholders are interested in and complement technology upgrades. Retrocommissioning is a process of evaluating the performance of an existing building's systems to identify problems in efficiency and then using this information to adjust the settings and calibrations to ensure maximum efficiency. While upgrading technologies is beneficial, the usage and settings of the technology are equally important and should also be considered. Similar to retrocommissioning, behavior change is an affordable way to reduce energy usage before investing in retrofits. Behavior modifications can also assist in maximizing the energy savings achieved from technology upgrades. For example, any light that is switched off, regardless of type and energy efficiency, saves more energy than even the most energy-efficient light when left switched on. These are both simple solutions to make minor improvements to a building before making the larger investment of installing new technologies.

6 Recommendations

The work of this project will be incorporated into *BEC's project: The Economics of energy efficiency in the Built Environment – Developing the tools for making decisions on cost-effective solutions*. Due to the short amount of time as well as the narrow scope of this WPI project, we were only able to collect a small portion of data for the larger BEC project. In this section, we have identified ways to use and improve upon our research, additional stakeholders and experts for future interviews, potential future projects, and recommendations for building managers and owners who want to increase the energy efficiency of their building(s).

6.1 Furthering the Research from this Report

We provided specific data for 14 technologies and a list of additional technologies that we could not research due to time constraints. We recognize that the scope and time of this project were limited and have recommendations on how to use and expand on the data provided in this report.

Further research on technology costs and electricity fees can provide additional monetary data and are best provided using price ranges. When compiling information on our list of recommended technologies, we often found that data provided on the cost savings, capital cost, and payback period of each technology were very limited. Data on capital cost were limited because they were reliant on the prices provided by the technology suppliers. Cost savings data were limited because they were dependent on each building's electricity service charges. Because the capital cost and cost savings data were needed for the calculation of the payback periods, data on paybacks were also limited. However, with further research on each technology, a range of values can be estimated for each of the missing sets of data. After collecting examples of electricity fees and equipment cost data from a variety of common technology and electricity suppliers, a range of values for each technology's capital cost and cost savings can be estimated. BEC plans on performing modeling on each of the technologies, which will be a useful way to calculate ranges for the payback periods.

Limitations: While the ranges provided by performing this research would be a useful aspect of the report, building managers will still need to consider their own situations carefully. There are many other variables specific to each building and situation that are not included in these calculations. For example, the final capital cost of a technology is often also dependent on initial installation fees, which vary greatly depending on the technology's compatibility with the existing building and required retrofits. Also, in many cases, the initial cost of a technology varies widely based upon the installation and energy efficiency desired, since there are often many different models and devices provided by technology suppliers, all ranging in complexity and initial cost.

Further research can be conducted to include technologies not covered in our report. During our eight weeks in Hong Kong, we were able to research 22 different technologies. However, throughout the project we learned about many additional technologies we had not yet come across in our initial research. While we performed further research on some of these technologies, we identified 59 technologies that were not researched (Appendix E). This was mainly due to the limited time frame we had to complete our project, and the project's limited scope of electricity saving technologies in existing commercial buildings. Further research can provide more information to building managers on technologies not yet included in CSB, EBP, or EMSD.

Limitations: In some cases, the time frame was not the only limitation and a technology was not included because information on the technology was not readily available. Researching additional technologies will require additional time, as well as further interviews and case studies to back up data collected through research.

The interviewees and companies who provided information for the case studies compiled in this project can be contacted to gather additional information that was not previously provided.

This report includes 24 case studies compiled from multiple sources. However, there was certain information, such as detailed descriptions of specific practices, missing in some case studies. Follow-up emails were sent to the sources to ask them for clarification on such details, but unfortunately, some sources were unable to provide additional information because the information was confidential, unavailable, or sources were unable to get back to us in the limited time. Additional information will improve the quality and detail of the case studies.

Limitations: Correspondence with sources takes time as they may be busy. In addition, very little can be done when information is proprietary or unavailable.

Conducting additional interviews can increase the statistical base of the data and allow for more accurate baselines. Restricted by the limited time available, only 16 interviews with 19 interviewees were conducted. With a small number of interviewees compared to the large scale of Hong Kong, data collected from interviews could not be used to identify broad trends. Instead, the data from this limited group were used to support technological research as well as identify attitudes and awareness of energy-efficient technologies without drawing conclusions for the entire city. Increasing the number of interviews would provide a more accurate representation of Hong Kong's current uptake and attitude toward energy-saving technologies. The interview protocols that we followed proved to be successful in gathering useful data. It is additionally important to identify appropriate interviewees based on their expertise.

Limitations: Interviews require time and manpower at every step of the process, with having to schedule, conduct, and analyze each one. Conducting enough interviews to create a representative sample size for Hong Kong would be an enormous task. Supplementing or substituting entirely the additional interviews with alternative sources of information such as questionnaires can reduce the number of interviews needed to obtain a representative sample.

The questionnaire can be used to establish a baseline of technologies used if it is modified and if it reaches a larger group of people. The questionnaires were only sent to those interviewees who agreed to fill it out. Additionally, the interviewees only had a week to return the questionnaire. Thus, we only sent out 12 questionnaires and received 9 back. This small number of questionnaires was not enough to establish a baseline, but we believe that a larger, and more statistically reliable, number of responses could provide this. An additional issue we faced with the questionnaire was that many of the responses lacked some of the detailed information that would provide more quantitative data on specific technologies. Some interviewees stated that the questionnaire was too long and that some of the questions asked for information that they did not have access to. We recommend modifying the questionnaire to ask which technologies are being used, including additional technologies from Appendix E, and not include detailed questions about specific technologies. It is an easy way for the respondents to identify the technologies they use in their buildings, do not use in their buildings, and those that are unfamiliar to them. This modified questionnaire can be sent to building managers and owners to gather a general idea of what technologies are being used.

Limitations: Questionnaires often have low response rates and can be difficult to give incentive for recipients to fill them out. It may also be difficult to get the questionnaire to reach a representative sample of building managers in Hong Kong.

6.2 Additional Stakeholders and Experts

We recognize that we had limited time to conduct interviews for this project and thus were only able to interview a small range interviewees. We have identified additional stakeholders and experts that can provide useful information to supplement the information we gathered from interviews.

Conducting surveys of building tenants will make the final project more useful to building managers by improving the understanding of the limitations and barriers tenants face, as well as their opinions on energy efficiency. The tenant perspective is important to energy planning because tenants and building occupants are the primary people who will be impacted by the energy-efficient upgrades and changes that are performed by the building owner and manager. A survey of changes tenants would like to see can assist building managers in making decisions for particular buildings. It is also important for building managers to understand the barriers that tenants face to be able to both assist the tenants in making individual changes, such as the lighting in a unit, as well as make the overall building changes, such as the central air conditioning system.

Limitations: It may be difficult to get in contact with building tenants. A potential way to do this would be to give the survey to the building managers to distribute to their tenants.

Conducting interviews with individual building managers will assist in developing a baseline of the uptake of energy-efficient technologies. During the interview process, interviews were primarily conducted with sustainability managers who were responsible for managing multiple buildings. A majority of these interviewees provided a general understanding of the common technologies used in their buildings. While this information was useful, it could not provide a detailed description of all the technologies used in an individual building. Some technologies are included in only a few buildings and interviews with the managers of those buildings can provide more detailed information. Conducting interviews with managers of individual buildings can provide a detailed understanding of the technologies used within the building in addition to helping to develop a baseline of the current uptake of energy-efficient technologies in Hong Kong. For example, during the interview with Interviewee 05, a manager for an individual building, we were provided with a detailed explanation of the technologies and the practices employed to improve the energy efficiency of the building. Additionally, interviewing individual building managers can help in developing an individualized understanding of what managers may want as the outcome of this project as well as help in creating a baseline criteria for managers to look into when installing energy-efficient technology.

Limitations Identifying potential interviewees may require further inquiry of current contacts to gather new contacts.

Interviewing hotel managers can give a more varied perspective on the barriers faced and their opinions on energy efficiency. Many building managers were interviewed during the project, some of which also managed hotels. However, none of them were exclusively hotel managers. Instead, most had a large array of buildings to manage, including hotels. Several interviewees mentioned that when dealing with hotels, specific barriers such as lease arrangements, and maintaining an emphasis on presentation had to be kept in mind (Interviewee 1,2). A more focused perspective could be gained from interviewing managers who specifically work with hotels.

Interviews with professionals from the EMSD can provide further information on specific technologies to reinforce and supplement the data included in this report. The EMSD has been conducting its own research and has provided studies on many energy-efficient technologies. This information was useful during the desk-based research section of our project and EMSD is cited frequently throughout the report. We recommend interviewing experts from the EMSD to gather additional information and case studies, and help make sure that information provided in the project report is credible and accurate.

Limitations: Interviews are time consuming and are best if they are conducted by at least two people so that one can conduct the interview and the other can take notes. These potential interviewees may be difficult to contact and may require further inquiry to reach the most appropriate experts.

6.3 Recommendations to Building Managers

We identified barriers to the uptake of energy-efficient technologies and have recommendations for building managers and owners to assist them in making their buildings more energy-efficient.

Energy usage data should be collected and monitored before planning and also after completing retrofits. In this report we identify that lack of detailed information about current energy usage is a barrier to the uptake of new, energy-efficient technologies. Using meters for monitoring energy usage to understand which systems are using the most energy is an important first step to increasing the energy efficiency of the unit or building (Interviewee 03). The data from the energy meters can be used to plan the best strategies for the particular client and give useful information on which areas to focus retrofits on first. Each building and unit is different and the technology upgrades should reflect this. Additionally, the energy usage before the retrofit can be used as a baseline to compare with energy usage after the retrofits to better understand the energy savings achieved by the new technology. It is important to continue monitoring the energy usage in order to evaluate the success of the retrofit and be able to track the progress and calculate the savings that have been achieved. Feedback from metering systems can also support efforts to change user behaviors.

Limitations: Companies will need to invest in metering systems to monitor the energy usage. Companies may the simple solution of investing in technology to reduce energy usage rather than investing time into monitoring the energy usage.

Planning ahead for energy-efficient retrofits should be expected by building managers, and can be productively combined with other types of maintenance and modifications planning. Multiple barriers can be solved by planning ahead for retrofits. Retrofits can be scheduled to correspond with the end of a technology or system's lifespan in order to minimize the waste of replacing them too early. Because many technology upgrades will not be compatible with the existing system, planning ahead for retrofits can allow for the maximum number of technologies to be upgraded at once. These retrofits can also correspond with previously planned ones such as routine maintenance and modifications to units while they are unoccupied during a gap between tenants. Costs are also minimized by optimizing the time taken and work done during retrofits. Building owners and managers should also consider if there are any energy saving opportunities when unexpected or unplanned work comes up.

Limitations: Planning for retrofits can be time consuming and requires a lot of information to be considered. Building managers may not want to wait until the optimal time to perform the retrofits.

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Authorship

Cameron contributed to the writing of every section and edited most of the sections. He performed all technology research alongside Thomas, and worked with Thomas on authoring the deliverable lists of technologies for the BEC. Cameron also wrote the weekly review documents in preparation for each of the team's weekly advisor meetings, and would organize the team's tasks into a weekly calendar. During the interview process, Cameron performed a balance of both interview conducting and note taking. Following the interview process, he worked alongside Nikhil in coding and compiling the case studies so they could be included in the report.

Nikhil contributed to the writing of every section and worked on editing multiple sections of the report. Prior to the interviews, he also wrote the standard interview questions with Rebecca. He assumed lead responsibility for the interview preparations by completing background research and writing specific interview questions for a majority of the interviews. During the interview process, he was primarily involved in conducting interviews. Following the interview process, he worked alongside Cameron in coding and compiling the case studies so they could be included in the report.

Rebecca contributed to the writing of every section and was the primary editor of the report. She did much of the behind the scenes work of organizing and tracking the information and data, communicating with interviewees, and all of the formatting. Before the interviews were conducted, she wrote the standard interview protocol and wrote the standard interview questions with Nikhil. During the interviews, she took and compiled the notes.

Thomas contributed to the writing of every section, and edited a small amount of them. He worked with Cameron to research technologies and author the deliverable list of technologies for the BEC. He also wrote some of the emails to coordinate interviews, and wrote notes for as well as conducted interviews for a large portion of them.

Report Authorship (**Wrote**, *Edited*)

Abstract (**CAB, RLF)**
Acknowledgements (**RLF,** *CAB*)
Executive Summary (**RLF,** *NMC, CAB, TV*)
Glossary (**NMC, CAB**, *RLF*)
1 Introduction (**RLF,** *TV, CAB, NMC*)
2 Background Section

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2.1 Energy Use in Hong Kong (**RLF,** *NMC, CAB,*)
2.2 Hong Kong Organizations (**TV**, *RLF, CAB, NMC*)
2.3 Motivations and Deterrents to the Uptake of Sustainable Technologies (**NMC**, *CAB, RLF*)
3 Methods
3.1 Interview Methods (**RLF,** *CAB*)
3.2 Compile a List of Technologies (**NMC, RLF,** *CAB*)
3.3 Create a Description of Technologies (**CAB**, *RLF*)
3.4 Identify Benefits and Barriers to Adoption (**RLF**, *CAB*)
3.5 Compile Case Studies (**TV**, *RLF*)
4 Findings/Results
4.1 Technologies and their Advantages and Disadvantages
4.1.1 Baseline of Technologies Used in Hong Kong (**RLF**, *CAB, NMC*)
4.1.2: Lighting (**NMC**, *CAB, TV, RLF*)
4.1.3: Air Conditioning (**TV,** *CAB, RLF*)
4.1.4: Lifts and Escalators (**CAB,** *TV, NMC, RLF*)
4.2 Barriers to Adoption
4.2.1 Lack of Information (**RLF, NMC**, *TV, CAB*)
4.2.2 Product Lifespan (**RLF**)
4.2.3 Compatibility (**RLF**)
4.2.4 Tenant/Landlord Conundrum (**RLF**, *NMC*)
4.2.5 Costs (**RLF**)
4.3 Benefits of Incorporating Energy-Efficient Technologies
4.3.1 Long-term Cost Savings (**CAB**, *NMC, TV,*)
4.3.2 Improved Corporate Image (**NMC**, *TV*)
4.4 Other Considerations (**RLF**)
4.5 Case Studies (**NMC**, *RLF*)
5 Conclusions
Recommended Technologies (**CAB**, *NMC)*
Barriers (**RLF**)
Benefits (**NMC**, *RLF*)
Other Considerations (**RLF**)
6 Recommendations (**CAB, NMC, RLF, TV**)
Appendix D Case Studies (**CAB**, *NMC*)
Appendix E Short List (**CAB, TV**)
Appendix F Long List (**CAB, TV**)

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Appendix A Interview Protocol

A.1 Introductory Email

Dear ___,

I hope this email finds you well.

As you will know, BEC is carrying out a project on energy efficiency technologies in buildings, supported by our Energy Advisory Group. This builds upon previous work – *Every Building a Powerhouse*, and *Carbon-Smart Buildings*. The current study aims to develop tools for property owners and managers to make decisions on cost-effective energy efficiency solutions. For more information about the project, you may refer to the 1-page description of the project attached here.

As part of this project, we will conduct interviews to gather information about current use of energy efficient technologies and practices in buildings, and experiences related to using such technologies including the costs and benefits. This part of the project will largely be carried out by a team of students from Worcester Polytechnic Institute, USA, who are here on a global projects program undertaking a related research project on improving the energy efficiency of existing buildings. They are have about 3 weeks to complete these interviews, during normal business hours.

We welcome your participation (or that of a suitable colleague) in an interview at a time and venue that suits you best. The interview will be confidential, and the collected data will not be associated with you in the report. Interview questions will be sent to you in advance, and we expect the session to take about 45mins.

We would be grateful if you can let us know who it would be best for us to speak to, and we can proceed to find the best time for the interview.

Thank you in advance for your assistance.

Thanks and regards,
Jonathan

A.2 Interview Outline

Send in Questionnaire and Technology list before interview

Introduce us

Disclaimer (have a print out for interviewee as well)

Thank you for joining us today and participating in this interview. You can refrain from answering any question or stop the interview at any time if you wish to. All answers that you give will be kept confidential and anonymous. Before we start, we would like to ask you whether you still accept to take part in this interview. Do you give consent to us recording the audio of this interview? The recording will only be used by our team to refer back to what we discussed and assist with making our notes for our own analysis and records. It will be deleted upon review. You will have the right to request to review the notes we take and we will send them to you as a part of our follow-up.

Introduce BEC's project and explain our role

BEC is conducting a project titled The Economics of Energy Efficiency in the Built Environment – Developing the tools for making decisions on cost-effective solutions. This project aims to support buildings owners, managers and tenants to make the right decisions on and develop a business case for investing in the energy efficiency of buildings. It will provide guideline figures as to the most cost-effective solutions and describe the most impactful technologies for reducing energy usage in existing buildings.

The WPI students are assisting BEC with data collection for this project, and will be working with BEC until late February.

Give an Introduction of what we know of their company. Acknowledge their position & company's business. Ask them to explain further and clarify

Interview Questions. Tailor this to each interview. Pull questions from questions from the appropriate categories. Refer to the list of technologies and keep them in mind as the interview progresses

Go over questionnaire

Recap at the end

Ask for possible references

Send follow-up email with questionnaire, notes from the interview if they asked to review, and anything else we/they said to follow up.

A.3 Interview Questions

Property Manager

- What type(s) of buildings(s) do you manage?
- Why is Energy Efficiency Important to your company?
- In your experience, is it easy or difficult to retrofit buildings in Hong Kong?
- How often do you retrofit your buildings?
    - What are your criteria for retrofitting?
- What are some of the most common technologies you implement in retrofits?
    - Skip if no retrofits
- What are some of the most common barriers when retrofitting?
- What are benefits you have noticed after completing retrofits?
- What do you think is a reasonable payback period for retrofits and technologies used in retrofits?
- What are some of the most effective incentives for retrofitting buildings?
- Is there anything the Hong Kong government could do to help overcome these barriers?
    - Incentives?
- Are there any retrofits you know of, that you would like to begin using but have not yet? Why?
- Are there any specific examples of retrofit projects that were notably successful in terms of increasing energy efficiency or had difficulties that you could tell us about? Or any specific energy efficient buildings you manage that would like to talk about?

Property Developer

- What type(s) of building(s) does your company develop?
- Why is Energy Efficiency Important to your company?
- In your experience, is it easy or difficult to construct new buildings that use more energy efficient technology?
- What criteria do designers/engineers account for when selecting the types of technology to include in new buildings? Where does energy efficiency rank among these?
- What are some new technologies you have begun using in new buildings to make them more energy efficient?
- What are some of the most common barriers to including more energy efficient technology in the design of a new building?
- What incentives (if any) would help you to begin using more energy efficient technology in your designs?

- Is there anything the Hong Kong government could do to help overcome these barriers?
    - Incentives? Providing information on new technologies (EMSD)?
- Are there any new technologies you know of, that you would like to begin including but have not yet? Why? How did you learn about them?
- Are there any specific examples of projects that were notably successful in terms of using energy efficient technology, or had difficulties that you could tell us about?

Hotel Manager

- What type of hotels do you commonly work with?
    - 3 star or 4-5 star?
- Are there any specific barriers for energy efficient retrofits in hotels? Please explain
- How much control do you have over a hotel's decisions on whether or not to retrofit?
    - How often are your hotels retrofitted? What kinds of retrofits are completed?
- How easy/difficult is it to initiate sustainable changes given the property owner and hotel are different entities?
- Does your hotel do anything to encourage the hotel guests to limit energy usage?

Energy Efficiency Advisory Companies

- Generally speaking, which types of buildings or clients would you most commonly work with, in terms of the following building types:
    - Hotels
    - Offices
    - Malls/commercial
- What are some of your most noteworthy clients (and types) in these areas?
- When looking to lower overall energy use, what are the most common technologies that you choose for retrofitting?
    - How frequently are they used in Hong Kong?
- What are some of the things you look for when deciding whether or not to use a specific technology or practice with individual clients?
- What are some of the most common barriers to the adoption and usage of new energy efficient technologies? From your perspective? From your client's perspective?
- Do you know of any new technologies that could have a positive impact on Hong Kong, but are not yet being used in the city?
    - Why are they not being used? What could be done to increase usage?

Technology Supplier Companies

- Are there any devices that you would recommend we look into, in terms of their energy efficiency, and cost effectiveness for use in Hong Kong?
    - What would be the overall benefits of adding this technology to a (new/existing) building?
        - Focus on initial and long term cost
    - What are some drawbacks of adding this technology to (new/existing) buildings?
    - Are there any barriers to installing this technology in a (new/existing) building?
- How common is the uptake of the technologies you have mentioned?
    - Would government be able to increase this, through incentives perhaps?
- Do you have anything you would like to add that has not been covered yet?
- Questionnaire with technical information

Recap Questions

- Repeat some of what has already been said and the objectives of the interview.
- From your experience, are there any technologies or practices that you would recommend?
- Do you have anything to add on the topic that we have not yet covered?
- Do you know of any people/companies you recommend we talk to for more information

Appendix B Post Interview Questionnaire

B.1 Building Developer/Manager/Owner (Questionnaire A)

Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Used in Your Building(s) Mark "most" or a "few" of your buildings	Not Used but familiar with	Unfamiliar with
Lighting Systems			
LEDs			
T5 Fluorescent Lamps			
Light Emitting Capacitor (LEC) Exit Signs			
Room Occupancy Sensor			
Daylighting Sensors			
Air Conditioning			
Chilled Beams			
Oil Free Chillers			
Variable Speed Air Conditioning			
Variable Flow Control for Condensing Water Pipes			
Air Source Heat Pumps			
Water Source Heat Pumps			
Electrical Installations			
Varying Fans and Motors			
EC Plug Fans			
Smart Meters to Track Energy Usage			
Sensor-based, Demand-controlled Devices			
Lifts and Escalators			
Linear Synchronous Motors			
Regenerative Braking			
Service On Demand Escalators			
Elevator Destination Control Systems			
Performance-based Approach			

Task Lighting Design			

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

- ■

Please list any case studies of the installation of specific technologies or general energy efficiency retrofits you can provide information for:

- ■

(Please copy and paste the following questions as needed for additional technologies)
For each technology used in your building(s) please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology________:
What, if any, benefits have been seen from using this technology?

- ■

What is the initial installation cost for this technology? Per installed device and/or per square meter of the area where the device was installed?

- ■

What are the savings (if any) recorded over time in both monetary and energy terms?

- ■

How easy is it to integrate this product into an existing building and to install this product in a new building? What are some barriers to installing and utilizing this technology?
Please explain your answer.

- ■

How many of your clients/buildings use this product?

- ■

What is the total floor area this technology is operating in?

- ■

Additional Information or Comments:

- ■

B.2 Energy Advisory Consultants (Questionnaire B)

Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Recommend to Clients Mark "Often" or "Sometimes"	Never Recommend to Clients	Unfamiliar with
Lighting Systems			
LEDs			
T5 Fluorescent Lamps			
Light Emitting Capacitor (LEC) Exit Signs			
Room Occupancy Sensor			
Daylighting Sensors			
Air Conditioning			
Chilled Beams			
Oil Free Chillers			
Variable Speed Air Conditioning			
Variable Flow Control for Condensing Water Pipes			
Air Source Heat Pumps			
Water Source Heat Pumps			
Electrical Installations			
Varying Fans and Motors			
EC Plug Fans			
Smart Meters to Track Energy Usage			
Sensor-based, Demand-controlled Devices			
Lifts and Escalators			
Linear Synchronous Motors			
Regenerative Braking			
Service On Demand Escalators			
Elevator Destination Control Systems			
Performance-based Approach			
Task Lighting Design			

Please list any other energy saving technologies not listed in the categories above that you recommend to your clients:

- ■

Please list any case studies of the installation of specific technologies or general energy efficiency retrofits you can provide information for:

- ■

(Please copy and paste the following questions as needed for additional technologies)
For each technology recommended to your clients, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology________:

What are your reasons for recommending/suggesting this technology?

- ■

What are the benefits of using this technology?

- ■

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- ■

What are the savings (if any) recorded over time in both monetary and energy terms?

- ■

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- ■

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- ■

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- ■

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- ■

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- ■

Additional Information or Comments:

- ■

B.3 Technology Developer/Supplier (Questionnaire C)

Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (Mark with X):

List of technologies	Supply	Develop	Neither Supply nor Develop
Lighting Systems			
LEDs			
T5 Fluorescent Lamps			
Light Emitting Capacitor (LEC) Exit Signs			
Room Occupancy Sensor			
Daylighting Sensors			
Air Conditioning			
Chilled Beams			
Oil Free Chillers			
Variable Speed Air Conditioning			
Variable Flow Control for Condensing Water Pipes			
Air Source Heat Pumps			
Water Source Heat Pumps			
Electrical Installations			
Varying Fans and Motors			
EC Plug Fans			
Smart Meters to Track Energy Usage			
Sensor-based, Demand-controlled Devices			
Lifts and Escalators			
Linear Synchronous Motors			
Regenerative Braking			
Service On Demand Escalators			
Elevator Destination Control Systems			
Performance-based Approach			
Task Lighting Design			

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

- ▪

Please list technologies that you develop/supply that you can provide us with data sheets on:

- ▪

(Please copy and paste the following questions as needed for additional technologies)
For each technology supplied or developed by your company, please type in information under each question to the best of your ability. Answer spaces are marked with the '▪' bullet points:

For technology________:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- ▪

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- ▪

What are the savings (if any) recorded over time in both monetary and energy terms?

- ▪

How easy is it to integrate this product into an existing building and to install this product into a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- ▪

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- ▪

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- ▪

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- ▪

Additional Information or Comments:

- ▪

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Appendix C Interview Notes

C.1 List of Interviewees

Appendix	Interviewee ID	Company	Category
2	01	A	Property Developer/Manager/Owner
3	02	D	Property Developer/Manager/Owner
4	03	C	Property Developer/Manager/Owner
5	04	REC-Yau Lee Holdings	Hotel Building Owner
6	05	F	Building Manager
7	06, 07	B	Energy Advisory Consultant
8	08	I	Energy Advisory Consultant
9	09	K	Technology Developer/Supplier
10	10	G	Building Manager
11	11	J	Building Manager
12	13,14,15	L	Energy Advisory Consultant
13	16	M	Technology Developer/Supplier
14	17	N	Technology Developer/Supplier
15	18	O	Technology Developer/Supplier
16	19	P	Technology Developer/Supplier
Email Correspon-dence, No Interview	20	Q	Technology Developer/Supplier
17	21	R	Technology Developer/Supplier

Note: Some interviews to be rescheduled to after the completion of the project and had already been assigned ID numbers

C.2 Interviewee 01

Interviewee ID: 01
Company ID: A
Category: Property Developer/Manager/Owner
Interview Duration: 1 hour
Audio Recording Allowed: No
Interviewers: Cameron, Nikhil, and Jonathan
Scribes: Rebecca and Thomas
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Can you tell us more about what your company does and your role in the company?
Company: property developer with 80% of Business in Hong Kong and 20% elsewhere (China, Singapore, etc.)
Additionally, they are landlord too and lease offices, shopping malls, and hotels after property development.
30% not property related
Other information: Conglomerate, Registered in Hong Kong

Can you tell us more about your role in the company?
Corporate Sustainability manager
Acts as a secretary for the group. Coordinates efforts of different subsidiaries (property management, property development) and their health and safety managers to meet sustainability goals of the company.

How important is energy efficiency to your company with respect to the buildings?
High. Energy efficiency has cost implications, so it is important. Better energy efficiency leads to lower costs

How easy or difficult do you think it is to make your buildings more energy efficient?
A difficult situation [for making buildings more energy efficient] is when the building is not owned by the group. It gets complicated because they are just managing it and the owner may be unwilling to make changes and improvements. While they can encourage, propose, and suggest

sustainable changes, they do not have the ability to make the changes 100% certain despite their commitment to energy efficiency

What energy saving technologies does your company use in the buildings?
Cannot name them all because I am not a building manager. The company adopts new technology in design and during retrofitting.

How often are Company A's buildings retrofitted?
This depends on the lifespan of the equipment. We will not replace [retrofit]equipment for the sake of making it better and will replace when lifespan is over.

What is the criteria to retrofit?
Compatibility: The new equipment must be compatible with the existing systems.
Cost [for retrofits]
Payback period, 5-7 years (reasonable)[for retrofits]

What are common energy efficiency technologies or practices?
Energy management systems (Company R etc. provides hands-on systems)
Air Conditioning uses a lot of energy so a major one to replace

Have you noticed any technologies with specifically high paybacks?
They pay more for new systems
Changing lights to LED is good although you have to consider the people; the architect and tenants must be satisfied.
[in terms of technology paybacks]Money, users, and feasibility must be considered
Compatibility is often a major issue
This is not an issue for new buildings because it is built from scratch/
Existing building require a lot of calculations and testing before proposing the retrofits.

What are some recent notable retrofits with Company A's buildings?
Company A's Headquarters [notable retrofits example]
Just replaced equipment
Phased out the older chiller plant and added a new air conditioning system.
Chillers were previously not allowed to be placed on the roof so they had wind type.
Replaced energy management system
The contractor committed that there will be a 4 year payback to this project.

On average, what is the size of the hotels leased by Company A?
He will get back to us
Follow-up:

Please find the no. of rooms & GFA for the hotels as below:
Hotel A1 – 447 rooms, 323,167 sqft.
Hotel A2 – 699 rooms, 410,945 sqft.
Hotel A3 – 435 rooms, 293,942 sqft.
Hotel A4 – 688 rooms, 303,870 sqft.

How do they encourage hotel guests to be more energy efficient
It is very limited what they can do. There are privacy issues and they cannot ration or control the water/electricity usage.
Can only encourage the guests. [in the hotels we manage, we] Have tried placing stickers near switches saying to switch off lights and TV when not in use, but this is not reliable or effective. [hotel managing]
The 5 star hotels have an automated shut off to the air when the room is not booked.

What are retrofits that are specific to hotels?
Hotels are not good a example for energy efficiency.
Their hotels are new (less than 10 years) so there is not current need to retrofit.
They are trying best to make smaller changes in the meantime such as changing lighting first (to LED) and turning off escalators when not in use. They are also using sensors.

All of the Company A's hotels have different names, are they leased?
Hotels run with a group owning the name/brand and operate the hotel, but do not own the building. They lease the hotel from a property developer (such as Company A).
We own 4 hotels and lease the buildings to other hotels and share the profit.
Peninsula group is an exception where they own buildings their hotels operate in.

Who is in charge of retrofits to hotels?
The hotel facilities manager is in charge of this [retrofits] and they will work with the owner works with them

Who has more incentive to retrofit the hotel? The owner or the brand?

This depends on priority. If the brand prioritizes sustainability they will be more likely to retrofit.
American hotels are usually less environmentally conscious.
They work together with the managers
As the building owners [of hotels], we do not feel enough pressure from the hotels to retrofit.
I would like to see the hotel owners have the initiative and then we will cooperate and help the hotel make the changes [retrofits]. It is the hotel brand name that is known, not the owner of the building, so it is in the best interest of the hotel and not the owner.

What are some questions or advice for us to include in future interviews?

These questions are similar questions to other interviews I have had.
The questions depend on the people.
I suggests you interview energy producers (CLP, service providers) to get more specific technology information.

What are barriers and obstacles to making buildings more energy efficient?

The compatibility of the building with the new technology as well as the costs and payback periods being cost effective.
Incentive:
Owners can provide incentive because the tenants are willing to pay for the electricity as long as the equipment is still usable (regardless of the energy efficiency).
The government could provide incentives (financial). Timing is important for government action because right now property costs are high so energy efficient changes would add to that cost. The public does not like to see the increased cost for energy efficiency.
Obstacles
There is waste generated from switching to new technologies. It is wasteful to retrofit before the lifespan is over. They need a plan/roadmap of when to retrofit based on the lifespans. Despite wanting all of their buildings to be the most energy efficient, they cannot change in a minute.

Can you provide us with more technical information regarding the sustainability of Company A?

Check the corporate website for sustainability report. There will be a new one released at the end of the month.

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C.3 Interviewee 02

Interviewee ID: 02
Company ID: D
Category: Property Developer/Manager/Owner
Audio Recording Allowed: Yes
Duration: 1 hour 10 minutes
Interviewers: Thomas, Nikhil
Scribes: Rebecca, Cameron
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

(Gave a description of our understanding of the company) Can you elaborate on what Company D does and what you do?
Company D is quite large and there are different areas of specialties. I am responsible for the environmental services they provide. In most situations offer integrated services to their clients with comprehensive coverage of areas including: planning, initial design, further designs, detail design, construction drawings, and commissioning projects. Sometimes only part of these services are requested by client. If they take a prominent role, they focus on environmental. Sometimes work with others in a team providing environmental assessment green building, site investigating, waste management, and sometime environmental impact assessment of site. I might not be able to answer questions about electrical and mechanical installations to help improve energy efficiency. We do a lot of carbon emission calculations for buildings [Company D]. Other aspects in terms of electricity consumption will fall under the engineering group and the electrical and mechanical team.

We see that you worked on [Buildings]?
Company D, not me, worked on that

Why is Energy Efficiency Important to your company?
I think energy efficiency is an important element to everyone, you do not want to waste any unnecessary energy. The basic is switch off the light when you're not in the office. We recently changed to more energy efficient lighting and that is using equipment to help with efficiency. There are other means to monitor. Nowadays people talk about smart buildings, that have the

ability to help you to turn off the light and AC if there is no movement. They also might monitor CO2. Not everyone is using it, you guys are working on that aspect. To a larger extend to a lot of the buildings are rented and it is not easy for the tenants to invest [retrofit]. They often do not want to invest [retrofit] unless it pays back within their lease period (3-6 years). Most people will say it is a good idea, but need to see how it is going to help. There are different approaches to deal with it [energy efficiency retrofits]. If the landlord is willing, they may charge a premium for the rent [when retrofitting] because they are giving the tenant a more energy efficient building. Hopefully you can reduce AC cost during lease period to cover the premium. There are things you guys can help think about to give more incentive for landlord to do. New buildings tend to be better because they have economic incentive from the concession that they can get from BEAM certificate, so they can bill more to cover cost that they invest. They can also get GFA concessions [Gross Floor Area (GFA) Concessions are granted if they meet] *Issues now are more related to existing buildings. There are a lot of them and they last for at least 50-100 years before being redeveloped. Redevelopment takes place quicker in HK. Another issue, when looking at long term sustainability knocking down buildings sooner. Inherent in HK, because older buildings are not utilized fully so people will knock them down.*

Do you think incentives or information from the government will help?
Buildings are being leased for tenants. If you have a retrofit system in place, it is good from the tenants perspective if it is provided by landlord, but what does the landlord get? Most office and commercial buildings charge per square foot for rent and separately for air conditioning per square foot. If they can reduce cost of the air conditioning unit, there is incentive for them. AC retrofit in general is more promising. The government started to allow water-cooling condenser for air conditioning. They previously discouraged it to save water, but Hong Kong doesn't lack water anymore as they get it from China. They relaxed restrictions on water-cooling condenser and that spurred retrofits because water cool units are more energy efficient. I don't know how much has been achieved. I think air conditioning systems need to be updated every 10-15 years maybe. There is always room to improve. The government can encourage district cooling, but at the moment there is only one area with district water-cooling to provide new buildings.

In this office they replaced lighting?
Replaced the old tubes to T-5. We just repartitioned this room just two weeks ago and reviewed some of the lighting. For me the room is too bright

Not very many people know about T-5s, do you think more information would help?
This was very easy, probably changed the light panel to allow this upgrade. Before we got the electronic ballasts. Different lighting requirements may dictate which type of lighting is used. For the lay person that [more information] may be useful. Although the EMSD has a website on this, but people may not be aware of it or know to look for it?

How often do you recommend retrofitting?
You don't want to retrofit until it is absolutely necessary. We don't have a norm. Renew the lease and then maybe an opportunity to look at it again. As a tenant, will not do anything major a few months before the lease is up. That is why it is probably more of an opportunity for landlord to retrofit air conditioning system if they are using less efficient unit that has come to the end of its lifespan. Best opportunity for existing buildings so they can offer high efficiency if they need to change it anyways..

How easy or difficult is it to retrofit?
It depends on what you are going to retrofit. For lighting, during major renovations is a good opportunity. For changing the chiller on the roof, the best opportunity is at the end of its lifetime because you need to change it anyways and it does not affect existing system. For example, [when retrofitting can be difficult] new glazing to reduce solar heat gain, will be quite major and the whole façade needs to be replaced, not as acceptable by the tenant and will incur quite a lot of costs. It is doable, but is a lot of effort. Needs to do it [retrofits] when tenant is not there or at the end of the lease. [retrofitting only between tenants is] Not very efficient. These obstacles affect major retrofitting for existing building. Air condition and lighting are easier. The tenant can have a say when they move in as they may do their own lighting and may use T-5 or LED if they know about it rather than the old technology.

What is the highest priority when deciding which technology to select when retrofitting? How much greater than the current technology would it need to be?
For most business operation, if you are going to invest, you want to understand the payback time and how much you can save with the new system compared with the normal/existing one. For example, under normal operation the old system uses $2000 and the new uses $1000. Might brush off the benefits from the energy efficiency by just looking at the every saving from the electricity bill. Unless they have a sustainability target: some companies have set how much energy savings they must achieve each year. I don't think we change the system just by doing the calculation on the payback, the old system became obsolete and the new system can sustain the environment. Ex. Changed the printer to double sided with standby and added card to release print job. If the company is committed to improve the sustainability, they will do something to help the environment. Energy efficiency and carbon emissions go hand in hand. I don't see the difference. Hong Kong relies on fossil fuel to produce electricity.

Do you have any stories of what your company has done to assist with creating case studies?
After the interview, will try to get you sustainability report in which we have some stories that might be able to help. [He gave us a copy] *If you need more, then ask but that should have some stories and statistic.*

Recap: it is a matter of tenant vs. landlord priorities:
Some landlords do not think they can benefit. Currently there is BEAM assessment for existing building. I think that is trying to help change people's perception of existing buildings. Some businesses will try to associate with more environmentally friendly building, but it is mostly new buildings. They are restricted to moving to newer buildings if people want to move into at least Gold rating building [for ex] and are just restricted to new building. This may be a driver. Some developers are starting the project and assessing their own existing buildings.

Are the government building energy codes helpful?
If you get new code [government], people will need to build to that standard as it is a requirement rather than voluntary basis. It is better than everything up to the developer. Again, [government building codes] this is only for new building application. Goes back to the issue of existing buildings.
How about government requiring new technologies in code for existing buildings?
It is a good thing to increase the demand for new technologies and will go to new research. [government] Code is difficult to apply to existing buildings

Do you have anything to add or ask us?
Not much to add. Interesting to see group from US to help BEC.

Would you say BEAM is important?
If you have a gold or platinum rating [BEAM], you have the buildable floor area increase without charge. They recognize if you build energy efficiency measures, they will grant you additional floor space to compensate for the investment. It is more difficult for existing buildings. The existing building BEAM program is just starting and we have yet to see the real benefit.

Explained questionnaire:
I will take a look at it and see what I can do. Some of my colleagues may be better suited to do this. I'm not sure if they will want to.

C.4 Interviewee 03

Interviewee ID: 03
Company ID: C
Category: Property Developer/Manager/Owner
Other attendees: Associate 03
Audio Recording Allowed: Yes
Duration: 1 hour 15 minutes
Interviewers: Nikhil, Thomas
Scribes: Rebecca, Cameron
Notes Compiled by Cameron

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Gave introduction:
Is the sample only in Hong Kong?
Scope is only in Hong Kong.

Gave our introduction of our understanding of Company C and Interviewee 03.
Technical services of sustainable development. Property portfolios, encouraging properties to improve sustainability. Company C Properties is subsidiary of Company C group; Company C properties will only look at property portfolios (mostly in Hong Kong, China, etc.) I is looking after all of the portfolios in Asia Hotels and restaurants are also managed under Company C Properties. I do not deal with day to day operations. I do not deal with technical operations either. I work on things here at the office instead. I Provide those who work on the day to day work with strategies, such as energy improvement programs. We will look at whatever we need to look at in order to be ahead of the curve in portfolios.

Why is Energy Efficiency important to Company C Properties?
Everyone talks about climate change and global warming and cares about the planet and the impact the portfolios have on the planet. As I said before, Corporate good citizen perspective is very important to this company. This will also help to save money by reducing electricity consumption. However,

changes will need to make sense for our investments' bottom line as well. As long as it does that, and allows us to be good citizens, we will do it.

For buildings that have mixed use (hotel, commercial, etc.) Are they more difficult to retrofit?

Not necessarily, we just need to understand what systems consume energy. We Start off [analyzing for retrofits] by collecting energy performance data. We Started to install energy meters to understand what installations consume in terms of electricity. We then Built up knowledge based data to understand how energy is spent. Once we have this idea, it is easier to manage individual buildings because we can understand how individual portfolios perform. This [gathering energy performance data] is not easy for buildings like [Building C], because it has been around for around 25 years. We just have to live with the fact that the basic system is not as advanced. We have been upgrading over the past 10 years with: building management system, circuit design, energy meters, 85-90% accurate to understand how each sub-circuit uses energy (i.e. fans, lighting, chillers). We are doing this earlier than many other developers. Believe in reducing impact on environment of the portfolios. Over 200 years of history (in Liverpool, UK) and almost 150 years (in Asia) caring about doing the right thing.

How often and criteria for retrofit?

Operation team for buildings will keep track of energy usage [when deciding criteria for retrofit]. We understand where energy is being spent and keep track of this to understand the energy management measures to take. We use knowledge based understanding to determine what changes we need. look beyond this and next year, set KPI, energy and carbon reduction targets for 2020 and 2030 that are endorsed by board. By the end of 2015, we have a 16% increase in floor area in Hong Kong with -16% (or %60) energy reduction since 2001. Company C Properties in Hong Kong is ahead of the curve here (in the private sector).

Start with the low hanging fruit: There is a lot of opportunity, for example replace chillers. Over the past 8 years have basically replaced all of the chillers in the 4 centers in Hong Kong. Chillers are the major energy spending. makes good sense in improving efficiency, making operation easier to control, more stable conditions, increased energy efficiency.

What is next? We are about to embark on a major monitoring based program on all our portfolios. We will begin [retrofitting process] by replacing the lights with LED's and T5 lighting. 60% of lights have already been replaced by LED's. We then Monitor the buildings to see how the new equipment is performing now that we have included these changes. We feel that now is the time for retro *commissioning. With new commissioning, we can deliver much better energy efficiency in our operations. We will start with Building C and each center will be 8-12 months to complete. New equipment and new commissioning will increase energy efficiency. We are taking a big leap in the industry by doing this as well.*

Difficulty of retrofitting depending on age?

Depends on the system. [difficulties in retrofitting] For older buildings without the energy meters, you need to invest in them. They need to have individual storage rather than relying on old systems. You need to consider what the objective is. For example, measuring temperature needs to be real time, but energy consumption can have a delay. Sometimes all you can afford is the energy meter, because you don't need instant data. You also need to [you need to] address the complexity of the building and give information on the building while spending an affordable amount. You have to keep the right amount of investment for what you need. For existing buildings, once the chillers are installed, we need to decide what to do next. According to our findings, the next thing you need to focus on is the air distribution side. That is more complex because you cannot disrupt tenants by replacing fans. You need a strategy to improve efficiency without interrupting tenants. The window period for retrocommissioning is usually when a building is between tenants. I would not say it is difficult, you just need to plan ahead. For example, you can replace systems during winter when it is not the peak season.

Specific technologies they used?

Associate 03: Payback period. Oil free chiller. Which one is more critical depending on the data. Do not have an absolute system, it is case by case. Understand constraints.

Interviewee 03: Since a design consultant usually thinks about technology, quite often it is on the property management side they fail because they do not understand the management of the system. The marketplace is filled with all of this technology, but it [technology within the marketplace]will not get best performance if not managed properly for the best efficiency. How are we managing what we have in the most efficient way?

For example, we did not invest in VSD chillers and were able to get maximum efficiency from the design of the constant chiller. Changed the pump into VSD (less expensive) and can still deal with changing load in reality. Going back, VSD chillers are always better. It's better to deal with it when it is a light load system, where it needs to be able to vary its speed. In a large building however, constant speed drives are less inefficient. We have to understand how

the cooling load is being managed. The new approach is called 'natural curve chiller control'. We are testing/staging them in our centers to see which work the best. The important thing is that we need to maximize the cost benefit. One of our new methods we are testing, is pairing up, or coupling chillers to maximize their energy use. New buildings are all VSD chillers.
; whenever we call upon a chiller, it must operation on its maximum, if not, can have a partner chiller to maximize. In Colorado, have first ever chiller control test. Not testing the ARI standard condition, testing the new chiller control curve to maximize the highest performance. New operation approach rather than new technology. Continuous experiment. Logic/design approach rather than product.
Different for existing portfolio. Use the big data to help inform the small data application.

Case studies
We are pioneering by adopting EC plug fans. Whenever a tenant is moving out, we can install the EC plug fan, testing it, conclusion is to reduce fan power by 40%. This is the kind of technology to install in new buildings. ASI system is bound to affect the tenant, install in between tenants. Considering how to implement it in other buildings.
Associate 03: Bell drive, bell will lose some efficiency. Normally bell drive with have one fan, EC plug fan will divide into smaller fans at higher efficiency. Proven by test case.

Hotels, are there any barriers for hotels specifically?
In retail we cannot control the tenant. For hotels, It is up to the landlord for basically everything. We were looking at, for example, the kitchens inside restaurants, and how we can use heat recovery technology there without it being damaged by the dirty air. which can come up with a lighting scheme,. Hotels using now are using: LEDs, and the circadian lighting concept (i.e. turn down lights at night to bring comfort and wellness in addition to energy savings). For hotels, we really need to look at the comfort of the people staying and working there.

Need to gather quantitative data, questionnaire.
Heat pumps are not common here (in Hong Kong). New ones [new technologies they are working on] EC fan. We are exploring chilled beams. The data is all internal and confidential. We need to take certain credit if providing data.

New building Rooftop integrated PV, grow the green roof and PV cell; tri-generation using biodiesel, is 2.5% of total building. Hong Kong government is considering renewable energy. Helping to reduce carbon.

Post-Interview Questionnaire A

Interviewee 03
Company C
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Used in Your Building(s)	Not Used but familiar with	Unfamiliar with
Lighting Systems			
LEDs	X		
T5 Fluorescent Lamps	X		
Light Emitting Capacitor (LEC) Exit Signs		X	
Air Conditioning			
Chilled Beams		X	
Smart Glass and Facade Treatment		X	
Oil Free Chillers	X		
Variable Speed Air Conditioning	X		
Variable Flow Control for Condensing Water Pipes	X		
Air Source Heat Pumps		X	
Water Source Heat Pumps		X	
Electrical Installations			
Varying Fans and Motors	X		
Controls and Smart Meters	X		
Sensor-based, Demand-controlled Devices	X		
Natural Lighting Controls	X		
Elevator Destination Control Systems	X		
Lifts and Escalators			
Linear Synchronous Motors		X	
Regenerative Braking	X		
Service On Demand Escalators	X		

Performance-based Approach			
Task Lighting Design	X		

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

- EC Plug fan
- Bio-diesel generator
- Chiller optimization controls

For each technology used in your building(s) please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology____EC Plug fan____:

What, if any, benefits have been seen from using this technology?

- It can reduce fan power consumption, no need to replace belt, bearing, minimization of maintenance

What is the initial installation cost for this technology? Per installed device and/or per square meter of the area where the device was installed?

- 20% - 30% initial cost increase comparing to conventional belt-driven fan

What are the savings (if any) recorded over time in both monetary and energy terms?

- reduce around 40% of fan power compared to belt-driven air handling unit

How easy is it to integrate this product into an existing building and to install this product in a new building? What are some barriers to installing and utilizing this technology? Please explain your answer.

- For new building, it only specifies this type of fan to replace conventional belt-driven air handling unit in the tender.
- For replacement of EC plug fan in existing building, it needs to consider the delivery of the EC plug fans to the air handling unit room, replacement sequence and time as it will affect the downtime of the system.

How many of your clients/buildings use this product?

- As we are in pilot scheme to replace this EC plug fan so it only replace several units in this moment and will target to replace about half in the future.

(Please copy and paste the following questions as needed for additional technologies)

For technology____Chiller Optimization Control____:

What, if any, benefits have been seen from using this technology?

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- Base on energy data to establish automatic operating system to operate chiller and associated pumps under a high operating efficiency to match with cooling load

What is the initial installation cost for this technology? Per installed device and/or per square meter of the area where the device was installed?

- The cost will depend on whether the building has sufficient metering to collect energy data for analysis and develop the software protocol to control associated equipment.

What are the savings (if any) recorded over time in both monetary and energy terms?

- If good chiller optimization control is implemented, it not only reduces energy consumption and also electricity cost. It has potential to save around 10% of the water distribution energy.

How easy is it to integrate this product into an existing building and to install this product in a new building? What are some barriers to installing and utilizing this technology?
Please explain your answer.

- For new building, it will be more easily to integrate into the design if budget is available as sufficient metering and sensing equipment shall be implemented.
- For existing building, if the existing BMS system is not advanced and supported transfer of lot of data, then it needs to upgrade BMS system and associated metering & sensing equipment.

How many of your clients/buildings use this product?

- All buildings allow this optimization control in the system. However, it needs to fine-tune the control logic when several years of operating data are available.

What is the total floor area this technology is operating in?

- N/A

Additional Information or Comments:

- It is on-going commissioning process as tenant's cooling load profile may be changed if new tenant move-in or renovation works carry out. Sufficient data shall then be collected and analyzed to ensure the optimization program is matching with cooling load requirement.

(Please copy and paste the following questions as needed for additional technologies)

For technology____Bio-diesel generator____:

What, if any, benefits have been seen from using this technology?

- Adopt bio-diesel to generate electricity and use waste heat to generate hot water for cooling (by absorption chiller) and heating (pre-heat domestic water)

What is the initial installation cost for this technology? Per installed device and/or per square meter of the area where the device was installed?

- Depend on the scale, it is around HK10,000/kW

What are the savings (if any) recorded over time in both monetary and energy terms?

- The bio-fuel generator will generate electricity for internal use and waste heat as by-product to drive absorption chiller to provide cooling. Therefore its self-generated electricity to support its own building equipment can save energy cost. The by-product waste heat for using absorption to generate chilled water can save electricity for conventional electric chiller can save energy.

How easy is it to integrate this product into an existing building and to install this product in a new building? What are some barriers to installing and utilizing this technology?
Please explain your answer.

- For new building, it will be more easily to integrate into the design if budget is available.
- For existing building, as bio-diesel generator requires additional plant space and associated accessories such as chimney for residual gas exhaust, connection between absorption chiller, connection between building power system and associated fire services provision for the new plant etc. which is barrier for application in the existing building.

How many of your clients/buildings use this product?

- One -- two new development will incorporate this technology

What is the total floor area this technology is operating in?

- N/A

Additional Information or Comments:

- Bio-diesel fuel in Hong Kong made of waste cooking oil transforms landfill waste to useful combustion fuel. Carbon is offset and methane gas generation via decomposition of organic waste in landfill is avoided. Therefore, advanced biofuels nowadays is likely to help reduce CO2 emissions by displacing the carbon-intensive fossil fuel combustion (e.g. coal and natural gas) if it is supplied from city electricity grid.

C.5 Interviewee 04

Interviewee: 04
Company: REC Engineering Company Limited, part of Yau Lee Holdings Limited
Category: Hotel Property Owner
Audio Recording allowed: Yes
Interviewer: Thomas
Scribe: Rebecca
Duration: 30 minutes
Notes Compiled by Rebecca

Holiday Inn Express - SOHO
Background, REC Engineering belongs to Yau Lee holding (small sized developer) We are very keen to invest on green tech, we believe that global warming is key and essential factor. If we do not do something, eventually the natural resources will be consumed. We invest on construction methodology. We are a building builder: we are main contractor, we have companies like REC, subsidiaries, they invest a lot on research and development we need to invest in R&D to have technology that fills clients needs. Manufacturers make what they think is suitable for the market, but they will not invest if it is not a good return. To us, a lot of solutions compose of software and hardware do not have manufactures for both software and hardware at the same time to fit implemented solution. Some history, in 2005 Yau Lee Holdings built a building in Causeway Bay (Hotel) but it was a time when people did not focus on energy efficiency and that was captured in the design. Only a small hotel (265 rooms) had a HK$5.7 million energy bill. The energy bill eats into the expenses and reduces profit margin. In 2002 we bought the land, completed in 2005. In the operation period we noticed killer energy bill. Fortunately we sold the building. By 2008 Yau Lee holding acquired REC, in 2010 we invested in land in soho again and worked with holiday inn to build a new hotel, this time we invested a lot in energy efficiency with a holistic approach including building orientation, material, energy efficiency, MEP, and a lot of control philosophy. Make sure the orientation and location is optimized; room rate is optimized, but the west side gets a lot of afternoon sun → make the façade on west side thicker. Introduced a lot of new building material Starfon (new material, cement based mixed with recycled paper and secret formula) the outcome is as hard as granite and marble and can print on it to look like granite and marble. If we install granite and marble, it is a lot of natural materials and excavation produces a lot of waste. We try not to use this kind of raw material as a group. In a sense of CSL,

a sense of invest, a sense of selling in the market. On the MEP side we introduced a lot of interesting technologies.

Control philosophy: In the design we need to push in fresh air into each hotel room, but the guests are often out. Why do we need to push air when the room is not occupied? We introduce damper for the fresh air to each room, by linking the smart card of the room, they take the card out when they leave the room and the air is reduced by 50% when they are unoccupied. That is a huge saving. This is not a kind of technology; it is a kind of solution. Most people do not bother to try this because they are afraid the hotel would operator would complain if there is anything wrong. But we as an owner and designer insist to invest. The building has been operating quite well. Not a lot of 3rd parties will offer to the client. We introduced a motorized curtain; most guests will leave the curtain open. If the window is facing east, a lot of solar energy will heat the rooms. We link the smart card and curtain. When they pull the smart card to leave, the curtains will close. A little bit saving, but the hotel operates 24 hours, 365 days. This is an interesting solution people often do not think about. People will not think about such minor details (not designer, consultant, or operator).

Hardware wise: we have R&D unit that develops technology. Intelligent fan coil unit. The traditional AC motor is very energy inefficient. We introduce DC motor and we have high intelligent control with it. By inserting the DC motor we eliminate the magnetization effect and energy is reduced by nearly 80% it operates with control unit, the controls for the room, set the temperature, the automatic control. Guests will often put it on high speed to cool off quickly, then forget to turn down fan speed, the energy efficiency cannot be achieved because it is high speed for long time. With the control, we have auto control it goes into high speed when you open the room and when the room temperature gets lower, the control will reduce the speed gradually to fit room temp. the user does not have to bother with the speed control. Another is corridor lighting; the corridor is not highly used during the day. We have new PRESS (Pattern recognition energy saving solution) used for common areas. It uses the CCTV to identify humans in the detected area to turn the light and AC on (they will be running half off). Motion sensors is useful, but it will turn off when people do not move where PRESS identifies the silhouette of a person, not the motion so it will still detect even if the people are not moving.

Hot water in a hotel is critical energy killer in hotels. In Hong Kong, not a lot of people invest in solar energy to heat hot water. We install on the commercial application large solar heat on the roof of a building. We studied the nearby area. In 2012 the government issued a guideline that defined saving the ridgeline to not block the view of Victoria Peak from the Kowloon side by 25% percent. So they know there will not be any buildings taller than theirs to shade the panels and can install solar hot water panel. Invest extra because it is heavy on the roof. We install 5 large water tanks on the top floor; need to design building to handle the weight. Closed loop *circulate the water it heats the hot water can build up to about 60C on a day like today. Can get up to 70-80 C in the summer. The water, coming in is about 17C, requires a lot of energy to heat. It saves a lot in the hot water side. We use heat pump at night, capture the waste heat from the AC. This saves a lot of energy. For AC, we have energy optimization solution in controls. Most building management systems are not intelligent enough because you have to implement by program and it does not take into concern the actual data in real time. We work with a professor in Hong Kong and we implement the paper. The main effect is to take in real time data (temperature, humidity, chilled water temperature, condensing water temperature) and calculate every regular interval (for example 5minutes) and recalculate the optimum operation point of the system. Tell the building management system to operate at that point. There will not be any extra energy to cool down a certain portion in a certain period because there is a quick response in real time effect. Building management systems work but are not fast enough, you lose the energy saving for the delayed hours.*

The building is awarded by (LEED, BEAM+, Singapore Green Mark, China Green Building Council) 4 international platinum awards. We arranged nearly 275 tours for industry, school, etc. a lot of stakeholders. This is the kind of education and information people need, as well as commercial sense, we influence them, we try to educate the students, not R&D, but unique thinking.

If I can take you through the building, Next Monday 11-11:45am tour of the hotel (an hour). Meet at the hotel lobby.

We invested extra. (Heat pump, starfon, etc.) ROI is 3 year nine month (4 years ROI completed). One extra thing, we did not install any PV panels (for the time being, the ROI is still 17 years) We do not bother with ROI over 5 years. The payback period is 4 years.

On next Monday, I will print information about it, there are 22 green implementations in the building. And I will share the figures (payback, energy saved)

We can use the name Holiday Inn Express Soho; Yau Lee Holdings REC Engineering limited.

C.6 Interviewee 05

Company ID: F
Interviewee ID: 05
Category: Building Manager
Audio Recording Allowed: Yes
Duration: 30 minutes
Interviewer: Thomas
Scribe: Nikhil
Notes Compiled by Nikhil

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Could you talk about the different types of buildings that your company manages?
Our firm manages two office buildings, warehouse in new territories, and bungalows for the staff for holiday purposes. Energy efficiency is one of the most important topic for our firm. There are quite a few things that happen in the Legal industry that are not always environment friendly. For making strategies, we make use of digital copies but in court, hard copies required and multiple copies are required. Hence, we are a big consumer of paper. To balance this, we pay attention to sustainability and the green aspect. As a result, the building is tried to be maintained at an energy saving level and environmental as possible.
We have not included many energy saving technologies and energy management systems.
We have a lot of focus on the human behavior as well as had a renovation project completed about five years ago. In the renovation, we have implemented the use of certain technologies such as LEDs. We have a green button system that when pressed, will turn the spotlights off. This can be used during the day because there are already sunlight coming from outside.
The benefits of using sunlight can be seen from the design of new buildings. However, this building is an old building that was built about half a century ago. As a result, the use of sunlight is quite minimal. In our office renovation, all the partitions were walls before. They are all changed to glass now. This leads to natural light penetrating the inside of the office and results in some savings in lighting.
We have shifted from non-open office design to an open office design leading to the improved ventilation.
A major waste of energy occurs when devices are kept in standby mode or are simply unused.

We have introduced a light watch software where all our computers, printers, etc. will shut off at night during a certain time. Those who wish to keep using them will turn them back on.
We encourage paperless usage and have green ambassadors in our firm.
We have no paper waste as we recycle 100% of our paper. We have reduced the carbon emission with our supplier and have annually reduced 20 tons of paper.
We have received multiple awards for energy efficiency of firm.
In Hong Kong, building are usually curtain wall types of buildings. About 60% energy usage is from commercial. Curtain wall absorbs sunlight and this reduces the use of energy. However, curtains are still down in the evenings, and nights. As a result, more energy is used to maintain the temperature and so can energy also gets wasted. This is contradictory to energy saving.

There are certain barriers to retrofit buildings and many times, it depends of Government. The government needs to provide more incentives to developers to include green aspects as a requirement. Most developers focus on maximizing the revenue.
Singapore has more of a focus of energy efficiency and green aspects. They use sky gardens and create an open environment for ventilation. Office buildings in Hong Kong don't have this as they want to focus on maximizing area use and increase the revenue.

In terms of energy saving technologies, we have seen that the investment for such technologies can be quite high and the return on investment is about 5 to 10 years. This is a major challenge for small and medium sized enterprises in Hong Kong as there any many of these companies that may not even exist for that long. This challenge could be overcome if the government does something about it or the technology becomes more affordable.
We are tenants and we can help by focusing on education. By encouraging the save water, save paper, save electricity system, we are trying to be more efficient.

How to deal with barriers of awareness?
The public is aware of the barriers but that has not had a major effect on the people.
The general public's habits or the living standard has not changed and as a result, they continue using the same technology. We have quite a long way to go. The only way to improve is continuous education and if that does not work, the government should make it mandatory.

Could have provide us with Case studies to show the power saving?
Our energy bill for the last 5 years has gone down by about 30%. The main reason for this is human behavior and the change in LED systems including the green button.
The landlord provides the air conditioning and as a result, no changes can be made by the tenants.

A new system is the use of mobile phones to control devices. That may be more inefficient and people may turn them on before they reach home. Convenience is one of the major barriers to energy efficiency.
The [] building is most energy efficient. It was designed about 40 years back and retrofitting is very easy there. They have sunlight collectors. The building is very well designed. All offices buildings aren't very energy efficient. In addition, zero emission facilities need a lot of open area and they cannot be used here because of the dense commercial area.

C.7 Interviewees 06 and 07

Interviewee ID: 06, 07
Company ID: B
Category: Energy Advisory Consultant
Audio Recording: Yes
Duration: 20 minutes
Interviewer: Cameron
Scribe: Thomas
Notes Compiled by Thomas

These notes have been modified to ensure the confidentiality of the interviewees and company. All responses are representative of their views and not of their company

Questions
Responses

Cameron- Is there anything you would like to add about your company?
Interviewee 06- *We are an international company that started in the uk, spread to Australia, and have some offices around the middle east and Asia, but none in the US. We tend to do certifications such as BEAM, and sometimes LEAD depending on our client. We also work closely with MEP engineers. We are quite well rounded*

Cameron- What are the most common clients you get?
Interviewee 06- *I personally work on a lot of offices with some retail.*
Interviewee 07- *In my work most are government, hospitals, public housing, private residential, and maybe on occasion, a hotel.*

Cameron- do you have any examples of clients that are notable
Interviewee 06- *Some notable buildings would be Science Park, and Building B2 which is under construction.*
Interviewee 06- *Some clients are []*.

Cameron- When looking to lower energy use in existing buildings, what technologies do you go to?
Interviewee 06- *Not new buildings?*
Cameron- No.

Interviewee 06- *We mostly do new buildings. A lot of the time, we are doing LED technology. A lot of our work is on old equipment, so we have to upgrade that. We get chillers to not be constant flow.*
Interviewee 07- *We make plans, such as behavioral; shutting off lights or computer monitors when not in use.*
Interviewee 06- *We also look into lighting controls and occupancy sensors.*
Interviewee 07- *40% of buildings energy use is in cooling, Because of this we suggest to use inverter type AC unit. VSD Pumps, especially in part load conditions*
Interviewee 06- *Which is pretty frequent.*

Cameron- What are the most significant barriers when dealing with buildings and energy efficiency?
Interviewee 06 and Interviewee 07 = *cost.*
Interviewee 07- *Government wants to be leader so spends a lot of money to get sustainability, but private companies prefer to save money.*
Interviewee 06- *They also like to only use proven technology.*
Interviewee 07- *They play it safe.*

Cameron- Are there any new technologies that you haven't seen being used yet?
Interviewee 07- *There is this thin silicon on glazing that can generate electricity on this layer. It basically uses sun to generate power off of this. Hong Kong is not interested as supply cost and labor cost is really high. Also building companies are interested in people being able to see the energy efficient technologies they are using.*
Interviewee 06- *People like to highlight their sustainability.*
Interviewee 07- *Phase change materials are also another one, used in building materials to increase thermal capacity of the building. It not very well known in Hong Kong*
Interviewee 06- *Also buildings in Hong Kong are not insulated very well; Hong Kong uses outdated calculation to determine thermal efficiency.*
Interviewee 07- *This is because the temperature difference is not very high. The envelope is only 5% of the contribution to energy costs.*
Interviewee 06- *Also air conditioning is not very efficient. They use split systems and don't use any conservation or heat recovery.*
Interviewee 06- *They could reduce cooling load this way. Another thing is there is not any on site energy generation.*
Interviewee 07- *Electricity bill is quite low in comparison to other costs.*

Cameron- Do you have any more case studies or any positive stories?
Interviewee 06- *Science Park has passive design principles which is very uncommon in Hong Kong. Very low energy use and high performance facade.*

Interviewee 07- *Not by our company, but wetland park uses the heat source pump technology. Their AC is 100% ground source.*
Interviewee 07- *In Hong Kong due to the groundscape, using a heat sources pump is not very good. There are lots of rocks, and not much water thus it is not very efficient.*

Cameron- Anything else you would like to add?
Interviewee 06- *Nope.*

Cameron- Is there anyone we should interview?
Interviewee 07- *Science Park.*

Cameron- Do you have anything from your work on Science Park we could have?
Interviewee 06- *Yes, we have public documents, and maybe more. Also, have you heard of the zero carbon building.*

Cameron- Thank you for your time.
Interviewee 06 and Interviewee 07- *You're welcome*

Post-Interview Questionnaire B

Interviewees 06 & 07
Company B
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Often Recommend to Clients	Sometimes Recommend to Clients	Never Recommend to Clients	Unfamiliar with
Lighting Systems				
LEDs	X			
T5 Fluorescent Lamps		x		
Light Emitting Capacitor (LEC) Exit Signs				x
Air Conditioning				
Chilled Beams			X	
Smart Glass and Facade Treatment		X		
Oil Free Chillers		X		

Variable Speed Air Conditioning	X			
Variable Flow Control for Condensing Water Pipes	X			
Air Source Heat Pumps		x		
Water Source Heat Pumps			X	
Electrical Installations				
Varying Fans and Motors	X			
Controls and Smart Meters	X			
Sensor-based, Demand-controlled Devices	X			
Natural Lighting Controls	X			
Elevator Destination Control Systems			x	
Lifts and Escalators				
Linear Synchronous Motors				x
Regenerative Braking	X			
Service On Demand Escalators			x	
Performance-based Approach				
Task Lighting Design		X		

Please list any other energy saving technologies not listed in the categories above that you recommend to your clients:

- CO_2 controls and monitoring on AC systems
- CO controls for mixed mode systems in carparks, for example
- Low-E glazing

For technology________: LED

What are your reasons for recommending/suggesting this technology?

- It is energy saving and cost effective, with good return on investment

What are the benefits of using this technology?

- Lower energy consumption, longer lamp life means fewer lamp replacements and waste as well

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The increase in lamp cost compared to conventional is 15-20USD per lamp for a halogen

What are the savings (if any) recorded over time in both monetary and energy terms?

- We have seen our projects save lots of money and electricity. Particularly in retail stores where the LED lamps replaced halogen lamps, which consume 5 or times more energy.

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- There are direct retrofit options available for some lamps, in which case it is very easy and can be done in stages to save cost. In new buildings, it can be more challenging due to the high capital outlay

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- It is very popular and increasingly used as cost of LEDs has decreased, making the return on investment period shorter. It is not a very popular replacement for T5 lamps at the moment, which are still relatively efficient

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- I would estimate at least 10 sites but could not estimate the total floor area.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- None, users hardly notice the change

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- In existing buildings, there are sometimes compatibility issues with the electronic

Additional Information or Comments:

For technology________: variable speed pumps, drives, fans, etc. or variable flow

What are your reasons for recommending/suggesting this technology?

- It is straightforward and simple, and has other benefits

What are the benefits of using this technology?

- They save energy in low load conditions, as well as reducing wear on parts

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- It will depend on the application, and I can't really estimate

What are the savings (if any) recorded over time in both monetary and energy terms?

- It will depend on how often the system should run at part load, and I can't really estimate

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- Not always easy in existing buildings, but very easy in new buildings. In existing buildings, this may disrupt operation during installation of the parts or it may not be compatible with the other equipment

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Quite popular and widely used in new buildings

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- Sorry I could not estimate the total floor area.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- It might require a bit more knowledge and effort to operate. Often, building operators override the variable speed/volume function and no energy savings are achieved

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Not sure

Additional Information or Comments:

-

For technology________: demand controls and sensors

What are your reasons for recommending/suggesting this technology?

- It is straightforward and simple, and has other benefits

What are the benefits of using this technology?

- They save energy by switching off or turning down operation as required

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Sorry I have no idea

What are the savings (if any) recorded over time in both monetary and energy terms?

- Depends on how often areas are unoccupied/low occupancy or how lazy users would normally be about turning off equipment

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- It is not always easy in existing buildings, but very easy in new buildings. In existing buildings, this may disrupt operation during installation of the parts or it may not be compatible with the other equipment

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Widely used

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- Used in most of my projects to some degree. Occupancy sensors to switch off lights or A/C are fairly common (lights more commonly than A/C)

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Often controls are overridden, but it should be easy

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Some effort to calibrate and commission properly

Additional Information or Comments:

-

For technology________: smart meters
What are your reasons for recommending/suggesting this technology?

- Smart meters make it easier to monitor usage, identify any unusual patterns and basically enables energy management. They are also relatively low cost

What are the benefits of using this technology?

- Same as above

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- It depends on the device, around 1000USD per device excluding installation cost

What are the savings (if any) recorded over time in both monetary and energy terms?

- It depends on the project

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- This is not always easy in existing buildings, but very easy in new buildings. In existing buildings, this may disrupt operation during installation (but not always)

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- I don't think there is anything similar to doing this, but it is popular

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- These are in most projects I have worked on, but I don't know the area this would cover

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Whilst installing the meter is easy, monitoring the reading and taking corrective action is another matter. There is additional effort involved to reap the benefits

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- None really

Additional Information or Comments:

-

For technology________: daylight controls
What are your reasons for recommending/suggesting this technology?

- This is relatively straightforward and simple

What are the benefits of using this technology?

- Saves energy in the right conditions, which in turn might reduce cooling loads and also increased lamp life

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- It can vary and depends how many controls and on the configuration. However, worth nothing that the BEC requires some level of daylight controls, so the additional cost compared to statutory requirements might be zero

What are the savings (if any) recorded over time in both monetary and energy terms?

- I don't know officially, but I think ~15% energy savings could be expected

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- Not always easy in existing buildings, but very easy in new buildings. In existing buildings, this may require rewiring or it may not be compatible with the existing equipment

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- It's quite popular and widely used

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- It is used in a lot of buildings, but never in my retail projects. Sorry I have no idea

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Sometimes the sensors are too sensitive or not sensitive enough. Sometimes they are overridden because of this

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- It can be disruptive to install this in existing buildings. Needs calibration and commissioning

Additional Information or Comments:

-

For technology________: regenerative breaking in lifts

What are your reasons for recommending/suggesting this technology?

- It saves energy and is a feature offered by most lift manufacturers

What are the benefits of using this technology?

- Saves energy and requires no effort for the operator

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Sorry I have no idea, I imagine there is some cost premium per lift

What are the savings (if any) recorded over time in both monetary and energy terms?

- I have not observed anything directly, but I have referred to this when talking to clients

http://www.emsd.gov.hk/filemanager/en/content_764/applctn_lift_rgnrt_pwr.pdf

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- This might not be easy in existing buildings, but very easy in new buildings if the lift with this feature is specified. In existing buildings, this may disrupt operation during installation of the parts or it may not be compatible with the other equipment

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- We recommend it a lot but I don't know how often it is installed

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- Sorry I don't know

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- None that I can think of

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Capital cost

Additional Information or Comments:

-

For technology________: task lighting

What are your reasons for recommending/suggesting this technology?

- It can save lots of energy (as long as the general lighting power is also reduced), whilst providing high quality lighting conditions

What are the benefits of using this technology?

- Reduced the installed lighting wattage if done properly, whilst providing good light for task work

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- This could vary, depends on how much the task lights cost. It could be pretty cheap!

What are the savings (if any) recorded over time in both monetary and energy terms?

- Sorry I have no idea

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- This can be easy in an existing building, but is even easier in a new building. In an existing building, it may require reconfiguration of lighting. For a fit out project this is easy to do since they will probably redo all the lighting anyway

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- This is not very popular, as it can make lighting designs less flexible and does require higher capital.

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- None that I know of in HK

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- This type of lighting design might result in a specialized general lighting layout. If the layout were to change the general lighting layout may have to be reconfigured.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- A proper lighting designer should be engaged, which does not happen on all projects.

Additional Information or Comments:

-

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C.8 Interviewee 08

Interviewee ID: 08
Company ID: I
Category: Energy Advisory Consultant
Audio Recording: Yes
Duration: 1 hour
Interviewers: Cameron and Maya (BEC liaison)
Scribe: Rebecca
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewees and company. All responses are representative of their views and not of their company

Questions
Responses

Maya: Gave an introduction to the BEC project: We had the energy advisory group (Energy AG) in BEC identified barriers to energy (proof of performance, really understanding the rest technologies) Take a carbon smart type approach to identify the right set of technologies do quantitative analysis to figure out the payback periods. WPI students are identifying the right set and understanding what is the current practice/norm. We also want to understand more about the barriers and hurdles.
Interviewee 08: *This is good context. I want to know more about Energy AG, Company I is helping the EMSD write retrocommissioning. Company I spearhead of this work as supplier and consultant to optimize energy performance. Focus on improving energy performance on existing buildings. Call ourselves an energy management consultant. There aren't very many in Hong Kong; Company B is more focused on new green building. Company I focuses on existing buildings.*

Cameron: Gave introduction of our knowledge about the company
Interviewee 08: *Services: yes energy audits, but there are also other means to get in. We are quite confident that every building will have room for improvement. Some clients have opinions on energy audit. We do retrocommissioning, monitoring based commissioning, energy assessment, fine fix and monitor, implementation support (improving stuff without an audit), and energy performance contract.*

Cameron: What is the most common building type you work on?

Interviewee 08: *Not really a specific sector, pretty much everything except residential. Do a lot of hotels, casinos, office center, commercial, quite fragmented, can be massive buildings, or smaller with retail chains. Target: anyone with annual energy bill of over $1 million USD a year.*

Maya: Do you have these numbers? Percentage of commercial buildings in Hong Kong with other 1 millions USD a year?
Interviewee 08: *EMSD. Building energy audit database; every building goes through an audit every 10 years. If you can push it, ask for it. Has energy bill baseline data. Will be very useful data. Ask them about EUI of each sector.*

Maya: We are looking for a picture/overview of energy usage in Hong Kong. Which ones are energy intensive?
Interviewee 08: *Data centers/banks are the most. Low profile. Hotels are energy intensive; the problem is that they are not owned. F&B [food and beverage] kitchens are energy intensive. Commercial and shopping mall is our smallest client: most of the properties are owned by the 5 biggest real estate in Hong Kong: Sun Hung Kai, Sino, New World, Henderson, Cheung Kong; they are big companies and I don't even know who to talk to; sustainability team and FM [facilities and maintenance] of each. Property developers and owners are quite a high one to crack. They say they have in house sustainability.*
Maya: We are not focusing on them [data centers] because they are a world on their own.

Cameron: We are creating a list of technologies to use further, what are some of the most common technologies you recommend?
Interviewee 08: *Our outcome is to reduce energy. There is a lot of other aspect, Company I approach is knowledge based energy management; there are many means and methods, technology is only one: operations/procedures use training. To rely on technology is not that fastest return. Ex. if you have a person to switch a light off, that is free. Control; not necessarily better technology, but controls it efficiently and fixes stuff, find what is wrong and fix them, change behavior and then retrofitting. Car ex. Don't start by upgrading the engine; look at the tire pressure, find things to fix first, train the driver's behavior, then do retrofitting and major work. Operation Maintenance, controls, retrofitting, technologies, Cap Ex (equipment exhange0. Some simple [solutions]: LEDs; many companies do not use LEDs. Chillers, chiller controls, pumps, chiller plant: it is finite (have up to 20 chillers). ASI equipment: terminal units [gestured to unit vents inside room] fan coil units; there are 10s of thousands in this building. HVAC: half of energy spent is on chiller and half is on ASI equipment. Chiller turns hot water into cold water that is pumped into buildings; waterside system: chiller, cooling tower, and pumps. ASI equipment: fan coil units, air handlers, VAV (variable air volume) up to thousands of these so a lot of opportunity. Often the logic of controlling equipment, how to control the equipment, how to pump, how much air is needed, is not focused. Like giving a car without teaching how to use.*

With a mix of chillers, which one to use when (ie during summer and winter) the demand profile, different chillers for different uses, logic and control sequence rather replacing.

Maya: How much can be achieved by fixing current systems and using controls?
Interviewee 08: Retrocommissioning. Commissioning is a process after design and build the building to fine tune it to match the intended use. Basically changing settings to optimize the building for the occupants. Retro Commission is doing commissioning when the building goes through changes (users change). Change the system to meet the use of the occupants. Fine-tune and find issues to optimize.
Maya: Need to decide how much Air conditioning is used in different parts of the building

Cameron: What are some of the most common barriers to applying new retrocommissions?
Interviewee 08: *Case studies. People want to know if you have done it before, where, how much, experience? Not that hard [case studies] for technologies: LEDs are proven, chillers are quite applicable.; technologies are relevant. Retrocommissioning and energy management is more difficult. and case studies.*

Cameron: Sharing case studies would be very helpful.

Interviewee 08: *We will need to make sure the client will be ok with it. Some we cannot disclose names.*

Rebecca: WPI report will not be disclosed; it will all be anonymized.

Maya: BEC will want to be able to publish names with the case studies.

Interviewee 08: *Clients may want the publicity of being associated with BEC. We will send the case studies. Let us know if you want to use the name in publication. Treat all as confidential, BEC follow up to ask for permissions*
Some of the most common barriers is people. What do I gain? What is the risk? Will I be rewarded? Key stakeholders in a building: facilities management, director of engineering; what is job description, is there time for this stuff? The department is often too busy, even to clean the filters, guests will complain. Engineers are risk averse people and will take low risk for energy management. Who is responsible for energy reduction, this means no one they expect others to do it. Energy is soft and fluffy and nothing gets done. Even setting targets is a lucky guess, often tasked with unrealistic targets. Ex: One hotel was getting a stringent target from HQ; previous improvements were not factored into the new year. KPIs are internal drivers as well as clear ownership. Client with dedicated energy manager has a clear dedicated responsibility. Need clear ownership of target and clear structure, a plan for improvement, performance feedback

(how to measure success). Need to be transparent, normalized. ISO management system: nothing to do with technology, that is the key. Tech can get you somewhere but need management.

Maya: KPI: Key performance indicators. Often lead to bonus. Allocation of time to invest into energy efficiency. ISO 50001: for energy management. Having a target and baseline will be in there.

Cameron: Are there any technologies that you recommend that have worked well?
Interviewee 08: *Lighting: LEDS will pay less than 2 years. T-5 outdated, LEDs are more efficient and longer life (50,000hrs) T5 (20,000 hrs). How much light you need: design level; removing a light is cheaper; delamping, task lighting, occupancy sensor, people do not like daylight sensors. Design side, there is a lot to be done. Façade lighting often lights up the sky Lux level. Shops like to be the brightest in competition.*

Maya: Need a narrative explaining the lights issues. Not as cut and dry. Façade lighting, do not light the sky. Can draw this out: commercial buildings are often lit up (esp. in central). Can still light them up more efficiently.

Interviewee 08: *Air conditioning: Oil free chillers, VSD (variable speed drive) chillers. Water side system: efficient chillers: (VSD and oil-free), putting VSD on pumps, cooling towers, VSD on fans. Air side: fans with ECM [electronic control motors] and VSD, PICCV (pressure independent characterized control valve). Hot water side: Heating should be heat pump instead of boilers; a refrigerant system not gas fired boiler or electric. Heat pumps are basically a reverse cycle chiller, use the waste heat from the chiller to heat the water. Capturing waste heat from the chiller to use to heat water. Every building will have cooling and often chuck it out the roof. Domestic hot water is used in Hong Kong; difficult and more complex in residential. Hot water is often electric instantaneous or tank gas boiler. A residential heat pump is larger, but too small for most of Hong Kong, could work for a villa. Air side control: a big field that no one has really mastered. What is the temperature set point, how do you control dampers, how much fresh air, how to efficiently distribute the air?*
Lifts/Escalators: Lifts spend small amount of energy. Can have regeneration lifts, but only for over 10 stories. Escalators are always on. VSDs on the escalators to detect occupancy and determine demand. Used more in Macao than HK. Services on demand escalators. There are a lot of escalators, in public places so they keep it running. Though they [escalators and lifts] are still a small amount of energy, probably less than 5% [building energy usage].
Maya: Focus on not only technology but cooling controls and human aspect of controls.
Interviewee 08: Thermal comfort. Over cooled buildings is an energy issue. Who sets the thermostat? the people who are working while the people are sitting so feel different temperatures. Human factor.

Cameron: Do you have anything else you would like to share with us?
Interviewee 08: *Technology is not the only solution. Other aspects: Fixing operation and maintenance, controls, technologies, driver/people. Technology will plateau at some point because technology is expensive. The other options are potentially more cost effective cheaper.*
Paybacks:
Lighting
LEDs. Under 2, max 3 years
Cooling
Chiller replacement 3-6 years
VSD: 1-3
EC motors 1-3
Heat pump: depends on the site, 2 years
Variable escalator: depends on usage. If they are not used all the time can be 1-3 (VSD).
Retrocommissioning: 1-2 years. There is a paper done by Lawrence Berkeley National Laboratory (LBNL). 5-10% of energy can be saved. Connect to building BMS, look at data, to monitor based commissioning (ex. 9% savings). Intercontinental Case study is retrocommissioning.

Maya: Look at city university case studies. Pick out the top technologies. Add payback periods to the questionnaire.

Interviewee 08: I do want to help with any kind of market information. BEC guide is a bit of a safety net. Barriers we see, the risk is less with following a guideline.

Post-Interview Questionnaire B

Interviewee 08
Company G
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Often Recommend to Clients	Sometimes Recommend to Clients	Never Recommend to Clients	Unfamiliar with
Lighting Systems				
LEDs	X			
T5 Fluorescent Lamps			X	

Light Emitting Capacitor (LEC) Exit Signs		X		
Air Conditioning				
Chilled Beams			X	
Smart Glass and Facade Treatment			X	
Oil Free Chillers		X		
Variable Speed Air Conditioning	X			
Variable Flow Control for Condensing Water Pipes		X		
Air Source Heat Pumps	X			
Water Source Heat Pumps	X			
Electrical Installations				
Varying Fans and Motors	X			
Controls and Smart Meters	X			
Sensor-based, Demand-controlled Devices	X			
Natural Lighting Controls		X		
Elevator Destination Control Systems			X	
Lifts and Escalators				
Linear Synchronous Motors		X		
Regenerative Braking		X		
Service On Demand Escalators		X		
Performance-based Approach				
Task Lighting Design		X		

Please list any other energy saving technologies not listed in the categories above that you recommend to your clients:

-

For each technology recommended to your clients, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology__LEDs___:

What are your reasons for recommending/suggesting this technology?

- Proven technology, energy saving percentage is high and evident (50% and higher);
- Easy to implement;
- Quick payback years – convincing to management;
- No requirement on facility management (i.e. control issue is irrelevant);

What are the benefits of using this technology?

- Dramatic price drop in recent years
- Quick payback (1 to 3 years);

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- Ease of implementation;
- Warranty coverage is usually good – 3-5 years;
- Lighting efficacy is good (Lumen/watt);
- Much longer lifespan of lamp (50,000 hr.), saving on maintenance cost.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The installation cost varied with contractors and the scale of installation, depending also on the client as well (some clients would use their preferred contractor, which is cheaper comparatively). The
- The total = Equipment cost + Installation cost (rewiring cost – manhour based), the equipment cost is usually competitive among suppliers, but installation would be dependent on contractor, if the quantity is large, the installation cost would be cheaper
- LED product that does not need rewiring is also available, but the equipment cost is higher, the total cost is roughly the same (with the rewiring option)
- E.g. Telco Project (more than 1,000 in quantity), per tube:
- ①Equipment cost = 50 – 100 HKD, ②Installation cost = 100 – 200 HKD
- ③Total cost= 150 – 350 HKD
- Per square feet/meter area is even harder to calculate –
  ①Certain lux level needs to be satisfy for different functional areas, the quantity varies and therefore recommendation does not use per square meter figure as base for calculation of saving
  ②The cost varies with contractors and quantity of lights

What are the savings (if any) recorded over time in both monetary and energy terms?

- LED saving on energy – 50% or higher
- LED saving on cost – 50%, dependent on operational hours, if 24/7 -50%, if 12/7, then 25% - but the payback is usually 1 to 3 years (otherwise would not recommend)

What is the average payback period for this technology?

- 1-3 years;
- Worst case- operation hour< 12/7, quantity is less than 100 tubes, then the equipment and installation would be high, the payback maybe even higher than 3. In that case, we would be less likely to recommend this to clients.

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- The installation is quick and simple (for retrofitting, some rewiring works may be required);

- Easy to have control options (e.g. wired to sensors).

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Very popular;
- This is one of the most implemented energy efficiency opportunities in buildings in Hong Kong

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- Almost all (as long as the payback is quick)
- Varied with projects, as long as applicable.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Brightness and produces glare– sometimes is too bright for people;
- Lux level requirement satisfaction – influenced by beam angle, specification);
- Retrofitting would require rewiring to satisfy detailed lighting installation requirements (HK);

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- No limitation on ballet; just need rewiring work/change the fixture. But not technology barrier;
- Need to consider the cost difference.

Additional Information or Comments:

- For the Hong Kong market, the total implementation cost varied mainly due to project scale (quantity of lights);
- For special requirements, e.g. Lux requirements for certain functional areas by certain Clients (no legislative/guideline requirements), LED types will need to be assessed to satisfy requirements.

(Please copy and paste the following section as needed for additional technologies)

For technology__Variable Speed Drive_:

What are your reasons for recommending/suggesting this technology?

- The saving on energy is evident;
- Quick payback.

What are the benefits of using this technology?

- Energy saving on each fan could be 20 – 30%;
- Improved indoor thermal comfort;

- Adding one point of control to optimize equipment/indoor ambient quality

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The implementation cost = installation + equipment cost, we have an in-house models to estimate the total cost based on the scale of the equipment (VSD), usually calculated as total cost/kW or cost/unit, the cost model is a logarithmic one based on equipment size or linear one based on equipment quantity;
- The smaller the VSD, the higher cost for each kW, it could go down to 600 HKD per kW,
- E.g. for VSD of rated power of 75kW, cost per kW is around 600 HKD, but for VSD of rated power of 7.5, the cost per kW could be as high as 1200 HKD.

What are the savings (if any) recorded over time in both monetary and energy terms?

- As stated before, the energy saving could be as high as 30% (with proper control logics)
- Cost saving would also dependent on the installation cost (which is based on manpower), but contractor would charge an daily onsite fee no matter how long the installation, so usually the larger the quantity, the cheaper the installation cost per unit.

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- Very easy, but need to consider the size of the VSD (the confinement of the building)
- VSD is equipment with specified input and output, also very easy to integrate to BMS (Building Management System).

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Very popular; as long as applicable, most client would go for the technology.

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- 100% as long as it is recommended and no obvious barrier as such space issue;
- Difficult to calculate the per floor area – it could be applicable to airside system.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- There will also be some programming cost for control logic implementation (usually easy and not expensive);
- It will add maintenance point(s) for facility management, and in other words point(s) of failure with regards to BMS or monitoring dashboard for the building;
- Need to be integrated to sensors to modulate the speeds of fans and have better control, so sensor coverage of the building may be a factor that impact on the cost-effectiveness of the technology;

- Energy consultant/advisor is recommended for implementation of control logics and sensor selection for control;
- If the VSD is still running on full load without implemented any operation logics, there may actually be an increase in energy consumption.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Space issue, particularly for old buildings.

Additional Information or Comments:

-

It is very important to understand that technology is not usually the most popular choice for energy efficiency opportunity due to cost-effectiveness, the popularity by efficiency opportunity could be illustrated by the following figure.:

- Operation & Maintenance (O&M) improvements (No to low cost, easy to implement),
- Control improvements (low cost, easy to implement),
- Retrofit/ Replacement (medium to high cost, relatively complicated to implement).

C.9 Interviewee 09

Interviewee ID: 09
Company ID: K
Category: Technology Developer/Supplier
Audio Recording Allowed: Yes
Duration: 40 minutes
Interviewer: Nikhil
Scribe: Rebecca
Notes Compiled by Rebecca

Our idea of company, is there anything you would like to add?
We work with many different companies, multinational or young, that have unique technologies. Our role and responsibility is to turn their concept into reality. We have our own lab and engineering team here. We do: OEM (original engineering manufacturing), ODM (original design manufacturing) and joint development projects. Fields are not just limited to home and green tech, also consumer lifestyle and medical. No matter where, the technology I see high level synergy across technologies. If buildings have sensors enabled, how we can monitor, can see trend of people utilizing sensors.

Our idea of your job, do you have anything to add?
I report directly to CEO. I am in charge of business development in addition to project management and research and development. My associate will help keep technology road map to drive new business.

How and why is energy efficiency import to your company?
Company K is still privately owned, not publicly listed. Public listed companies have a lot of governance. At the BEC meeting, we encountered LED light panel. I am still using T-8 in my office because we are not going to throw away the current technology and generate a lot of waste. There is no motivation for us to switch it out [T-8, if it is still working], even though we can manufacture a new tech. [if]An area [is] already going through renovations, we will do lights then. Retrofit is the bottleneck for decision-making. It is difficult to drive the awareness [of technology and good energy use] to the staff, if they cannot see it or understand, what is the message? They switch off the lights and AC turning off hours in the office or not being used. Do not have hardware to monitor the status. We have sensors to monitor the AC, light, and plug load. One side is the product and the other is the benefit.

When it comes to clients, what kind of barriers are there? How would you explain a technology if they do not know about it?

Showcasing is a good means to describe the tech itself. The customers are worried about the return on investment. They are many technologies available, how efficient is it?

When you are designing, what are the criteria?
For example light, companies claim they can manufacture a LED panel, if you look at the LED; it is good for durability and energy efficiency. However, if it is not designed well, ex heat dissipation, the life can be shorter. We cannot compete with the factories in China who can make it cheap, but the quality is not always good. How robust the design is. How reliable it is in the design. Company is set up for highest quality within an acceptable price level.

How do customers choose between different companies?
Customers often go to cheaper option[when choosing between two different tech suppliers]. Installation costs the same, the hardware is the difference, and cost is always the consideration, other than style. [customers of tech suppliers are also interested in]Quality, they will probably fall for well-established brands. We cannot compete with those big names.
Retrofitting, it is a big challenge we have systems for provide how much energy they use. Installation is the biggest cost driver for technology, not the hardware.

Are there specific technologies you recommend we look into?
Sensors are important and enable the measurements. [sensors are important and enable measurement]If you go for higher levels they will monitor and even further will allow the occupant to manipulate: the atmosphere, the time arrangement for the devices. Three levels: measurement, monitor, manipulate. We are a hardware company, not software, so measurements and monitoring. Commercial building: need to manipulate and collaborate with BMS (Building management systems). It is not the homeowners who can manipulate it; that goes to the property management not the tenant. Residential, there are devices readily available. Can use smart plugs and assess the data. For our business we want to strive for meaningful innovations. We always keep our eyes open for meaningful innovations and work with them to turn concept into reality.

Sensors are not that common?
They are relatively new. There are many ways to measure energy, plug, energy meter, current transformer. We went with this development to compare, we believe this technology can provide more explanation. There are many different devices, cannot tell, so do not know where the waste is. Actions are driven by what you do or do not know. We decided on these sensors because they can provide that information to make decisions on actions.

People do not know about the sensors…?
[for people who don't know about the sensors]Government is a driver. If the government takes the leading position, they installed meaningful tech and take a snapshot to compare and take specific actions and have results. This is a significant showcase. People expect government to

provide incentives. Ex. If housing authority needed to create homes, it is government subsidizes, it does not usually have facilities, just a building, everyone is in their own condo but the government could use the technology there and deploy part of it in the high density condos for a significant number of people.

Do you think building energy codes have had a positive impact?
As a resident, I [residents such as myself]do not get any education or advertising about codes. For appliances they show energy code in the store.
It depends on who it is, who cares. Resident cares about their home energy bill, but employee does not care. For government, 50-60% of people are living in government-subsidized building and over 400,00 families are in line for the government-subsidized homes. This is just my two cents.

Case studies
Sensors: It depends on how the building is designed. If installation is minimal, how can we get measurements without having to rewire, getting access to circuit breaker We are going to launch a case study [on our use of sensors]. Our sensors are new and not yet commercialized and are still in the field test stage.
PowerPoint: measurement, monitoring, the next step is manipulating, how can you remotely control it?

Post-Interview Questionnaire C

Interviewee 09
Company K
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (Mark with X):

List of technologies	Supply	Develop	Neither Supply nor Develop
Lighting Systems			
LEDs	X	X	
T5 Fluorescent Lamps			X
Light Emitting Capacitor (LEC) Exit Signs			X
Air Conditioning			
Chilled Beams			X

Smart Glass and Facade Treatment			X
Oil Free Chillers			X
Variable Speed Air Conditioning			X
Variable Flow Control for Condensing Water Pipes			X
Air Source Heat Pumps			X
Water Source Heat Pumps			X
Electrical Installations			
Varying Fans and Motors			X
Controls and Smart Meters		X	
Sensor-based, Demand-controlled Devices		X	
Natural Lighting Controls			X
Elevator Destination Control Systems			X
Lifts and Escalators			
Linear Synchronous Motors			X
Regenerative Braking			X
Service On Demand Escalators			X
Performance-based Approach			
Task Lighting Design			X

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

- Micro-metering system

For each technology supplied or developed by your company, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology <u>LED Lighting Systems</u>:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- Compact in size thus save space: New building and utilize this feature to create a more spacious environment. Retrofit building usually has fixed setting, but due to the compact size, LED lighting can easily custom to fit into the existing building fixture area thus reduce the need to have major renovation work to implement this
- Energy efficient: LED efficiency is one of the leading energy efficient solutions available in market
- Long life: LED lights product life is long life and can reduce maintenance cost
- Dimmable: LED lighting can be dimmable and can adjustable to different need and environment

- Decorative: Some LED lighting can change color besides brightness to cater for variety of needs as decorative purpose.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The cost varies according to different type and grade of light installed (e.g. bulb, panel light, spot light etc.) and the brightness required for the facility. In general, LED light unit cost is considerably higher than fluorescent light, ranging from 3 times to 10 times more expensive. However the number of LED light panel need to install to have the same amount of lumens is smaller, compare to fluorescent light and incandescent.

What are the savings (if any) recorded over time in both monetary and energy terms?

- Based on simulation, to achieve an average luminance of around 500 and could save around 60% of energy bill (thus energy) for an office running 12hrs/day and 23 days/month compare to fluorescent light. And the life of LED light can be 4-5 times longer than fluorescent light, thus reduce maintenance cost.

How easy is it to integrate this product into an existing building and to install this product into a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- Integration into new building should be relative easy as you can plan ahead the number of lighting fixtures needed accordingly. For existing building, as the lighting fixtures location and wiring are already fixed, the effort to change to new technology will be more difficult.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- Among LED light and fluorescent light, fluorescent light is more popular due to the lower start up cost.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- The design of LED lighting (e.g. heat dissipation, light guide or dispersion structure) requires certain know-how and there are quite some below standard fixture in the market that could not sustain long due to poor design and quality.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- To maximize the outcome, the lighting fixture location requires good planning.

Additional Information or Comments:

-

(Please copy and paste the following sections as needed for additional technologies)

For technology <u>Control and Smart Meter</u>:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- The CT smart meter we developed for customer is to provide a visibility of the total energy consumption for user and the user can use the information to verify the energy saving measures effectiveness.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The installation is relative simple and would only need electrician if installed in distribution box.

What are the savings (if any) recorded over time in both monetary and energy terms?

- The device mainly provides visibility and no direct saving derive from the device.

How easy is it to integrate this product into an existing building and to how easy is it to install this product in a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- The installation is relative simple and would only need electrician if installed in distribution box.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- Energy measurement can also be done by shunt instead of CT. The benefit of CT is the installation is simpler and can measure a large current safely.

What (if any) potential and or known drawbacks are there to *using* this technology in new and/or existing buildings?

- Energy meter can provide the total consumption but would be difficult to determine which area is most energy consuming.

What (if any) barriers exist to the *installation* of this technology in a new and/or existing building?

- The installation is relative simple and would only need electrician if installed in distribution box.

Additional Information or Comments:

-

(Please copy and paste the following sections as needed for additional technologies)

For technology <u>Sensors-based, Demand-controlled device</u>:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- Sensor-based and demand-controlled device are easy to install as it usually device-based, especially as IOT-able appliances and devices are getting more common.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Unless required to install an integrated system, controlling individual device is almost build in the device already. To have the devices to form into a network would require additional gateway or communication hub to centralize the control.

What are the savings (if any) recorded over time in both monetary and energy terms?

- Individual device saving will be of limited amount but if can combine with additional control protocol with utility company, it could help the utility to maintain a stable supply and if used with energy storing devices (e.g. battery, storage heater or immersion heater), surplus energy from utility could be saved.

How easy is it to integrate this product into an existing building and to how easy is it to install this product in a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- Unless required to install an integrated system, controlling individual device is almost build in the device already. To have the devices to form into a network would require additional gateway or communication hub to centralize the control.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- Sensor-based would be quite popular as the cost adder is limited to a device or an appliance. Demand side controlled will depend on the government policy.

What (if any) potential and or known drawbacks are there to *using* this technology in new and/or existing buildings?

- Security would be a concern if the device is cloud or network connected.

What (if any) barriers exist to the *installation* of this technology in a new and/or existing building?

-

Additional Information or Comments:

-

(Please copy and paste the following sections as needed for additional technologies)

For technology <u>Micro-Metering System</u>:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- This system can provide user a breakdown of electricity usage with limited additional cost and simple to install, comparing to CT and Shunt. With the visibility, the user can determine what action they should take and evaluate if the measures taken are effective.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- The installation cost is similar to smart meter but with the additional benefit of able to understand each section/area energy consumption.

What are the savings (if any) recorded over time in both monetary and energy terms?

- The device mainly provides visibility and no direct saving derive from the device.

How easy is it to integrate this product into an existing building and to how easy is it to install this product in a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- The installation is relative simple for both new and existing building. It is more beneficial for commercial or industrial building considering the ROI.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- This is a new technology for energy monitoring. The benefit to switch to this platform is that the user can see the consumption breakdown by each main circuit breaker in the distribution box without installing bulky CT on each breaker.

What (if any) potential and or known drawbacks are there to *using* this technology in new and/or existing buildings?

- The breakdown detected by the micro-sensor accuracy would not be the same as meter grade but can give the user a broad picture of how the consumption distribution is.

What (if any) barriers exist to the *installation* of this technology in a new and/or existing building?

- The system requires to mount an external device for the system controller and gateway and to install a CT to monitor the total current.

Additional Information or Comments:

-

C.10 Interviewee 10

Interviewee ID: 10
Company ID: G
Category: Property Manager
Audio Recording: No
Duration: 40 minutes
Interviewer: Thomas
Scribe: Rebecca
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Introductions
We provide consultation to our clients. If they want a corporate responsibility report, we will make one for them.

We explained more about our project.
The industry is looking for something very handy, they want to have things that they can do easily; this includes the payback. That will be useful.

What types of buildings and clients do you typically work with?
Mostly office and some commercial (retail, mall) and hotels are the least.

When working with the clients, what are the most common technologies you recommend?
Most clients will take handy options, for those retrofits, most are built less than 20 years. Just changing the lighting will save a lot. If they have more resources, they may change the chiller to a more efficient type or install equipment for heat exchange. Most of them will stop there; they will not ask for renewable energy because it is new and uncertain. They want a safe and guaranteed payback.

Other than lighting and chillers, are there other new technologies you recommend?
To my clients we will recommend smart meters, sensors, and timers. It is small amount of money to invest. The timer will switch off automatically. We encourage this type of installation. It depends on the project. If it just a floor or two it is easy to install sensors. If it is the whole

building we will recommend smart meters so we know the load and consumption by zone for specific tenants. This will help to check the actual performance because we can compare tenants who have and have not done retrofits for comparative study.

In this project we are looking for case studies, do you have any specific stories or clients you could tell us about?

Some are quite sensitive. We try to have benchmark performance for our clients, but there are difficulties because of data sensitivity. We are the one that manages buildings and we need to get consent from landlords and tenants. If you are doing well, you are more likely to share.

I think Hong Kong is better than 5-10 years ago by doing retrofits. Now we know about it but there is still a long way to go.

It comes to the accuracy of the meter. The meter is not that true in terms of how much consumption because: for example, electricity cost depends on the location (different utility companies have different prices) they also charge for peak hours and have demand charges. It is quite complex and not that comparable. You must compare same type and size of building, or compare per square feet. We tried to do it 2 years ago, but it was not successful.

This office: We did retrofit work 3 years ago. We got a workplace strategy and we wanted to put in elements (sensor, timer). We try to reduce the travel by using teleconferences instead of trips. We arrange the workplace with lighting, maximize daylighting, and choose different lighting modes. We mainly target the lighting, because we do not have much control over the buildings we manage. It is difficult to change the air conditioning system (highest demand) so we make use of the existing system.

In Hong Kong, how many spaces are rented vs. owned.

Most people lease buildings. Even if they own buildings, they will rent out that for higher rents and the owner may locate employees to a place with lower rents. Even when they own the building they will often outsource the building management.

Because of this complex relationship of owners, managers, and tenants, how does it work making buildings more energy efficient?

There are two ways: The better time is when tenants come in and they want an energy efficient building (usually international companies with global commitment) so they will look for green buildings (green lease); the demand is growing.

Second, the management already ISO 14001 (standard) by the time the tenant comes in they have to achieve commitment.

For stories we can share: Building G. We helped them to do precertification for WELL (similar to LEED, it is concerned about energy saving but also the people in the building, more requirements, i.e. how sleep cycle is impacted by lighting); this may be a new trend. I can send more information regarding the project.

Questionnaire, data on technologies themselves.
Yeah, you can send it to me

In Hong Kong, is it usually the tenants who directly pay for the electrical bill?
In Hong Kong usually the tenants pay directly to the electricity company, but it depends on the building. If they are of smaller size, they may not be able to occupy the whole meter such as smaller companies sharing space (small offices with common reception area). For this the consumption cannot be directly divided so it is included in rent. Usually it is paid directly by tenant.
That is why the bill is not on our hand; we have to ask door to door to get the information. Comparative to rent, electricity is fairly cheap, it seems like it is cheap compared to other parts of the world. In common years, the unit weight would increase for Hong Kong because of the commitment to reduce carbon emissions. We are shifting from fossil fuel to nuclear energy and natural gas, so the price will be going. The government will have some subsidies. They do not want to waste a burden on it. For Hong Kong, if you are using electricity, it is cheaper unit price for larger businesses.

Does this make it so there is less motivation to save electricity use?
At the corporate level they know electricity can be saved easily by installations and changing the habits of people. Habits are difficult (new people keep coming so they have to continuously tell people, but people get tired of the message). They will measure if the project successful by how many offices in the region have been retrofitting. This will be easier for them to indicate if it is successful.
People in Hong Kong know of the importance of being environmentally friendly, but may think that savings is minimal and may not have the time. Need to educate. I have seen improvement; we (Company G) have to issue guidelines for the company, i.e. specifications for when a light burns out. I think things are getting better in Hong Kong.
Also the user intensity here is usually pretty high. Even though we set sensors, the room is always being used so the sensor never turns off (It is set to turn off after 30 minutes, but the breaks between use may be only 15 minutes). It may be useful for common areas like the back corridor. For conference room, the sensor will turn on when people walk by the room and not actually go into the room.

Do you have anything you would like to add?
Do you have interest in investigate on the equipment energy saving for home? People always ask us about the computer. When you talk about the office building the main uses are AC, lighting, and then electrical equipment. People can control the use of the electrical equipment. Good for environmental education to give something that people can control.

I think if you are preparing a guideline, it would be good if it builds a model of how the tenant/landlord/manager can start the project, who they should talk to, how to plan, a checklist of what to do, and how they can monitor their usage and how it is working. That would be useful. I think people come to us and they have some ideas of what they want to do, they are not sure what to do and how they can start. The process. Office equipment is a good further place.

Post-Interview Questionnaire B

Interviewee 10
Company G
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Recommend to Clients Mark "Often" or "Sometimes"	Never Recommend to Clients	Unfamiliar with
Lighting Systems			
LEDs	**Sometimes**		
T5 Fluorescent Lamps	**Sometimes**		
Light Emitting Capacitor (LEC) Exit Signs			**Unfamiliar with**
Room Occupancy Sensor	**Sometimes**		
Daylighting Sensors	**Sometimes**		
Air Conditioning			
Chilled Beams		**Never**	
Oil Free Chillers	**Sometimes**		
Variable Speed Air Conditioning	**Sometimes**		
Variable Flow Control for Condensing Water Pipes	**Sometimes**		
Air Source Heat Pumps	**Sometimes**		
Water Source Heat Pumps	**Sometimes**		
Electrical Installations			
Varying Fans and Motors	**Sometimes**		
EC Plug Fans	**Sometimes**		
Smart Meters to Track Energy Usage	**Sometimes**		
Sensor-based, Demand-controlled Devices			**Unfamiliar with**

Lifts and Escalators			
Linear Synchronous Motors			**Unfamiliar with**
Regenerative Braking	**Sometimes**		
Service On Demand Escalators	**Sometimes**		
Elevator Destination Control Systems			**Unfamiliar with**
Performance-based Approach			
Task Lighting Design		**Never**	

Please list any other energy saving technologies not listed in the categories above that you recommend to your clients:

- Energy management system
- Dimming control for lighting

Please list any case studies of the installation of specific technologies or general energy efficiency retrofits you can provide information for:

- N/A

For each technology recommended to your clients, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology Variable Speed Air Conditioning

What are your reasons for recommending/suggesting this technology?

- Building operate at part load

What are the benefits of using this technology?

- Save energy for part load condition

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Not certain for this. Usually payback is around 3 years

What are the savings (if any) recorded over time in both monetary and energy terms?

- Not certain for this

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- Variable speed drive can easily been added on existing equipment and very widely applied for new building project as well

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- The technology is very widely applied

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- Almost 80%. Floor area is not certain

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Harmonic wave issue

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- No obvious barrier

Additional Information or Comments:

-

(Please copy and paste the following section as needed for additional technologies)

For technology__ LEDs **______:**

What are your reasons for recommending/suggesting this technology?

- More efficient than T8 lamps

What are the benefits of using this technology?

- Energy saving

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Around HK$100/lamps

What are the savings (if any) recorded over time in both monetary and energy terms?

- 50% saving compare to T8 lamps

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- Generally easy but sometimes need some re-wiring work

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Becoming popular but a lot of the buildings are still not applying it

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- 10%

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Sometimes it is too bright and may have some wiring problems

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Cost

Additional Information or Comments:

-

C.11 Interviewee 11

Interviewee ID: 11
Company ID: J
Category: Property Manager
Audio Recording Allowed: Yes
Duration: 25 Minutes
Interviewer: Nikhil
Scribe: Cameron
Notes Compiled by Cameron

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

[Nikhil recites disclaimer, explains project, and what we know about Company J] Is there anything you would like to add?
Other than the core business, we also have another business, in data centers, in mainland china. We also do manufacturing for the pipe lines. Our company has full scale for gas production. From upstream to downstream. We also have a company for software house. We are a multidisciplinary company.

Would you like to talk about yourselves? Your role in the company?
I am Assistant Environmental manager here. I am handling the environmental management and how we could implement environmental measures and initiatives, and incorporate a sustainability strategy here at Company J.
I am a senior technical officer; our team is in the property management section. I am mainly responsible for the E and M operation. We work on retrofit projects to enhance our energy usage. We are handling retrofit work in this building as well. We recently received a BEAM plus award for this building.

Why is energy efficiency important to your company?
Gov't has an energy saving plan, as of last year. Our company is also an energy company. Climate change also. Last month was one of the warmest in years here in Hong Kong. Government has set up many plans to push the private sector, setting up energy reduction targets. Especially here in Hong Kong. We are one of the biggest companies in Hong Kong to provide energy.

Even for the production and supply of our gas, we also use highly energy efficient technology. We also suggest energy saving technology to the houses we service. We have built up our own image, and energy efficiency and environmental protection is one of our missions in the company. Climate change is important. It is our responsibility to save energy and reduce impact of climate change.

Barriers?
As you know we are an existing building. It has a data center and a customer center. When we do retrofit works [on our own building], there cannot be any impact on our data operations. It is one of our difficulties. We also need to seek top management approval. We have to get consent for retrofits, which is one of our key difficulties. We don't want to effect the day-to-day operations.

Is cost also a barrier when retrofitting? Is cost a big factor?
The first difficulty after management approval is budget and money and payback. We have to tell them if it is worth it to do the retrofit. We have to save money after the retrofit as well.

Any other buildings that come under your management?
Some other buildings. Not under our team to manage.
Operations are very different. These buildings are mainly focused on gas line production. But here we are more focused on the management, hardware and software. Here we do it is very different, and are able to make it more energy efficient.

Would you mind sharing some about the tech in this building.
In 2013, oil free type water cool chiller was installed. One of the latest technologies in Hong Kong. Maybe in the US. One of the latest technologies in our building.
Motion sensors and LED lighting is also high end technology.

When it comes to shifting from T5 to LED's, they have to be retrofitted. Have you done this for this building?
Our building was retrofitted in 1994. We used T8 lights then. We then carried out another retrofitting project in... 2008 or something. We decided to install only two lights instead of filling all three spaces on the unit. [task lighting]. We also have installed motion sensors to maintain lighting use.
Any other technologies to recommend… such as air conditioning?
We think in AC the chiller plant is the most important thing. In our building we will study the effects of using a fan cooling system. We are also studying a lift power consumption. It is around 7% power consumption in our system. Lifts will come first for our retrofits, then fan cooling.

Any case studies?

Chiller plant upgrade project. We have saved about 1,000,000 KW-hours per year. Compared to previous chillers, the energy use is reduced by around 30-40%.

We would like to send the questionnaire.
Yes
Could you also send us some information on your oil free chiller project In your building? Anything you can share?
We could draft some short notes or paragraph to describe our retrofits on the chiller system. May not be too technical.

Is there anything else you would like to add? Technologies? You've talked about LEDs and Motion sensors
CO2 sensor to control our fresh air intake. monitor the concentration, to control our air intake. This is for the HVAC system. For lighting, it is sensors, LED, induction lamp.
*We adjust the chilled water supply temperature based on the season. Chilled water is 7*C, and return is 12*C. We've found it is too cold. In winter we adjust it to 12*C. In summer it is 10-11*C. We adjust it. It is one of the strategies to achieve energy savings.*
When installing these, since this is an existing building, what are the most important things you look into when retrofitting?
Return on investment, and detailed planning when we carry out a retrofit project. Main concern is to minimize its impact on day to day operations. This is our head quarters, so this is our main concern.

Any more questions for us?
Will you share the report to us at the end?
Nikhil: That's up to the BEC for their report. For us, our report will be public before BEC's is published.

C.12 Interviewees 13,14,15

Interviewee IDs: 13, 14, 15
Company ID: L
Category: Energy Advisory Consultant
Audio Recording Allowed: Yes
Duration: 1 hour
Interviewer: Cameron
Scribes: Thomas and Rebecca
Notes Compiled by Thomas

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Interviewee 13- *I was approached due to being the main contact for BEC, my role is to do the longer term development work for Company L. Interviewee 14 has been working with us on energy efficiency at the corporate level for 2 to 3 years, previously worked in our customer facing business. He has also worked on environmental issues. Interviewee 15 is technical expert, seasoned energy efficiency expert and works in our customer facing business.*

Cameron- gives background of our project

Cameron- is there anything else about the company after hearing our description

Interviewee 13- *Keep in mind, that electricity is not the whole game. Some buildings have diesel generators or gas for water heating or other applications, and if you look at the EMSD Energy End Use survey you can see where the electricity is going. People often say there should be mandatory electricity savings, and owners may simply switch to gas to save, but they may not very environmentally friendly. Take a look at the local kitchens, they use gas for woks in the kitchen, very inefficient, induction would be much more efficient. Take a look at all the fuels going into a building. Although not in the scope of your project but a good example is that in Vehicles, electric motors are much more efficient than fossil fuels.*

Cameron- out of all the buildings, which type uses the most energy

Interviewee 15- *Looking at EMSD data you can find these facts. They have all the figures for this.*

Interviewee 13- *in terms of energy end use, I think we should really look at buildings, as there are all types of sizes for malls.*
As you get more familiar you notice that Hong Kong is very tight packed, dense urban city. EMPORIS an American company counts the vertical density of a city. Hong Kong is number 1 in the world and is 4x as dense as New York which is #2, which means there is more escalators and elevators.
To answer the initial question is all of the above.

Cameron-Another part is incentives to promote, do you offer any incentives to customers
Interviewee 14- *There are Monetary, and nonmonetary incentives. The monetary incentive are to save money elsewhere such as electricity. Nonmonetary incentives are getting the green image or having a grade A rental. TRC test, in US, is whenever they incentives are delivered, they must be able to get back more benefits than what is put in. Some of these are reducing electricity bills, Social benefits and or improving the air quality.*
Interviewee 13- *There are two players in Hong Kong, the asset owner and the tenant. In Hk leases are very short, most tenants don't invest in a building as most of the time it is not worth it. Building owners may look to renovate a building because of image but with tenants, there may be other issues since Hong Kong rent is extremely expensive. You might want to take a straw poll to see if tenant would pay more than they already do for rent. Most would simply not want to pay for the highest level of building energy efficiency.*
Interviewee 15- *Company L, in order to improve the customer's efficiency, they can undertake energy audits every year. This audit helps a customer understand which area in their buildings has the highest potential for savings.*
Interviewee 13- *With our electricity users, 1% lowering in energy use creates significant savings.*
Interviewee 15- *Normally energy audit looks at some opportunities, as well as how to implement them, but sometimes there are more detailed studies to provide customers with data and studies to help them with retrofits.*
Interviewee 13- *We can do modeling, and then the customer can now grasp the savings. And then with these numbers it is much easier to convince CEO to implement changes.*
Interviewee 15- *We also encourage customers to look at online services to understand their profile, their consumption profile and make changes based on this.*
Interviewee 13- *Many larger energy users have smart meters. Smart meters are not yet generally used in medium and small businesses or homes yet. Because of this it is much harder and takes longer for them to get data on where they are using energy.*

Interviewee 15- *Users can combine weather reports with past usage data to estimate the energy use for a number of days ahead and then make changes that can save costs.*

Cameron-Any technologies you would recommend

Interviewee 15- *Normally air conditioning is the most important.*

Major recommendation is energy efficient air conditioning, from air cooling to water cooling heat pumps or to use oil free chillers.

Another area is lighting, and we have already been supporting customers to do lighting retrofits for more than 10 years. Now we provide and recommend customers to do lighting retrofit initially as it is easy to lower energy use.

Water heating is also good, using the air or air conditioning to use to heat water. Also changing out diesel heaters.

Interviewee 13- *Heat pumps could be in a lot of places in the city but they are not there. Some sectors have adopted (e.g. hotels) but some sectors (e.g. government) have been slower. If government has premises with an electricity target but no gas target – it makes it harder to adopt the switch to this more efficient technology.*

Interviewee 13- *Often improvements can offer multiple benefits. In the MTR, there are platform screen doors to keep customers safe. But they also save energy. They keep the cool air from leaking out and wasting it. This creates more benefits than you would think at first examination.*

Interviewee 14- *One of the common things people forget is it is not just all about technology but the insulation on pipes, and other simple things. It can all add up. Good maintenance goes well with using the technologies.*

Interviewee 15- *Maintenance is very important, this is very effective such as in condensers that are much more efficient when they are kept clean.*

Interviewee 13- *Also education is important, people need to know and change their behavior.*

Cameron- Are there any case studies that you have done that are particular noteworthy

Interviewee 13- *Some companies make it very public how they are saving, such as government, and the Link. which is a big landlord and is a listed business. Has many public markets and malls, and has been out to reduce energy use, published their savings and findings in newspaper.*

Interviewee 15- *MTR is doing a lot to save. They use regenerative braking, It is quite impactful. Most companies such as Swire are also doing a lot in energy saving.*

Interviewee 13- *You should look at green building council. Cary Chan who is the executive director at green building council also used to head energy advisory group at BEC.*

Cameron- anything else you would like to add

Interviewee 13- *I would like to add more about incentives the government should be doing to help businesses save energy. In US there are a lot of tax breaks. I am not sure if Hong Kong is doing enough in this area. You should look at Hong Kong and compare to US for policies for energy efficiency. BEEF, building energy efficiency fund, finished in 2013, and it offered rebates, half and half, for energy efficiency projects, and was generally viewed as very successful. Also there is RPP or reasonable payback period which depends on who you are; landlord or tenant. And the ratio payback thresholds in companies in Hong Kong are quite tough. Also know about the benefits for retrofitting such as health and others besides energy.*

What are some of the things you look for when deciding a technology for a company

Interviewee 13- *Technologies depend on customers.*

Interviewee 14- *It is also not just on the business but also knowledge for companies; they can use the money they have to get the most savings, and best impact with proper information. Education is a big barrier. Some of this can be fixed with audits, and also to give customers an idea of what they do have.*

Interviewee 13- *Energy advisory programs for SMEs are also important as many SMEs are run by very busy people.*

Interviewee 15- *Associations can help with information from them to place on the web for others to view and peer review.*

Interviewee 13- *Programs can be good when they educate the entire group of a particular trade of customers for easy comparison.*

Anyone else to go to and interview?

Interviewee 13- *Speak to government, green building council, Cary Chan and try to talk to tenants*

Questionnaire

Interviewee 13- *We recommend most of the ones on this list for our customers. However EC plug fan is not very popular in HK at the moment.*

Interviewee 14- *Lifespan should be remembered. What you are starting with is the important bit, planning how to implement new technology comes after that.*

C.13 Interviewee 16

Interviewee ID : 16
Company ID: M
Category: Technology Developer/Provider
Audio Recording Allowed: Yes
Duration: 45 Minutes
Interviewer: Thomas
Scribes: Rebecca and Cameron
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Disclaimer and Overview of Project
What we know about the company. What do you have to add?
Our corporation is quite wide in mechanical systems in buildings. We cover ventilation systems, energy savings, environmental products, indoor air quality, noise abatement, outdoor air pollution control. We have a wide range of products. Wastewater treatment in China, not just fire protection.
Company is mainly importer and distributor of innovative products. We do a lot with mechanical systems. We also do cleaning products, specialize products such as textile. Our main focus is products with element of environmental friendliness, sustainability energy efficiency, reduce waste, to maintain sustainability. We are looking into how to assist building managers, building contractors, building owners not only to construct, but to maintain buildings in a way that is sustainable.

You are the managing director?
Yes, I am the managing director and owner of the company.

In your experience, is it easy or difficult to construct new buildings with energy efficient technology.
It is quite easy, especially with new technologies. People were not engineering this into buildings because projects were managed on economic terms, not sustainable project. This is changing as the government has put out laws like the building energy codes. There is more to do to improve

on codes. It doesn't have to be expensive; it is attainable. Building Owners and people who finance the project need to think hard. I don't think it difficult.

When retrofitting old buildings, do you find it easy or difficult in Hong Kong?
Not difficult. For example we had to retrofit this office when we moved into this area. I hired a decorator, but I redid the designs because they were thinking conventionally. For example, I asked for a specific lux level based on a survey. They did conventional every other tile have a fixture. One of the largest lighting producers in the world told me to buy their cheap lights at about 128 Watts. They said 3 T-8 lights per fixture. Went to an Austrian manufacturer and they designed a lighting system with 2 T-5 to get the lux levels I wanted. I know have 50 watts per fixture rather than 128W. We are only using 105 fixtures; the original design was over 200 fixtures. People need to ask to get the correct design. I am paying more for the lighting fixtures, but reducing the heat load (for AC reduced) and energy consumption. People design up to the code level. In this office our lighting levels energy per sq ft. is 40% lower than energy code requirement.

What criteria do engineers use for designing technology for buildings and where does energy efficiency fall with these?
Energy efficiency rank quite low with designs. With retrofits, if the space is not of a certain size, they do not have to comply with codes. Normally it is up to the decorator. The decorator will follow aesthetics not energy usage. The owner needs to know what they want in terms of energy consumption. For ex. With AC, wanted an energy saving unit, variable speed one (inverter air conditioner) I was told it was expensive, but I said I wanted that over the conventional product. In the long run it will save me energy This needs to come from the purchaser. The engineers can only perform if they are given requirements to design at that level.

What are some other devices you recommend?
Oh yes, lighting is so easy to do. We do not have light switches in the office. We would need 70 switches, for every fixture and zone. Instead we have lighting/motion sensors. It will switch on one row of lights when you come in. We use wireless control to further control the lights. Save money on wiring. Have a control unit in each zone. This is very easy to do in terms of saving energy. We are not sacrificing any comfort level or management level with the lighting. Everyone seems very happy with the lighting systems we have. There are many other places people can look into to save energy; air conditioning is a huge consumer of energy. There are several means to save money on air-conditioning.

What are some barriers other than the upfront cost?
Barriers to upgrades, the knowledge is a barrier. It is not easy to relate what you are getting from lighting in terms of energy costs, it is not just about lighting levels, glare, tunnel effect in lighting. There is a lot that normal people would not have knowledge about. People who are

paying money to management to decide what to put in the designs; if they go for low budget, they are looking at short term (capital costs) rather than long term (capital costs and running costs). Energy savings is talking about payback overtime. All of this is about educating. This is something that has to penetrate through, otherwise people will choose cheaper. How do we explain that it is more expensive now, but it will pay back in some years. You can have more complex lighting management systems with LED. You can play with colors with LED or reducing glare. Need a combination of what they people want (they must know what they want) and the engineers then can put in place (they also need knowledge about the products). The people selling the products must disseminate the knowledge to all of the people from the owner/developer, to the architect, to the engineers, and to the contractors. (fill in here from recording). If someone along the line doesn't understand the product, they are going to select a product that doesn't match their requirements. The big lighting company tells me to go with the cheapest product.

What are some mechanical systems that your company works with that are relevant to our project (i.e. in terms of elevators and electrical systems)?
A lot of things can be done. For example, indoor air quality; we need fresh air, this can be better done to reduce energy costs and reduce the problems later on. For example if the humidity is too high in the outside air, it will cause problems with mold etc. indoors and will cause the fixtures and furniture to need to be changed sooner (3-5 years).
Top 3 elevator companies can offer energy saving technologies. Do not need energy to let it down, use gravity, producing heat when it goes down. Potential energy to kinetic to electric energy stored in battery. There are technologies available (for over 10 years), but is it cost effective? If more people use the systems, the cost will go down. Escalators, can go for variable speed. Building energy codes call for variable speed fans and pumps over a certain size, what about those smaller (that are not required by code)? There are lots of technologies out there that can reduce the energy. For example, can do variable speed for bathroom exhaust fan. There are hundreds of these in the building, which adds up to a lot. You have to look into everything that consumes power. You also have to change behavior. Most energy efficient lighting is when it is off. If you can't change behavior, use sensors. Our bathroom fans are fitted with sensors that reduce our energy consumption.

How common is the uptake of these technologies in Hong Kong?
It is not common. A big part is down to contractor levels around the street corner. These contactors are workers and have low-level knowledge of what is available and will bring the lowest price product to install quickly. They are not suggestion motion sensing and this and that. This is the lowest level. A lot of buildings do it this way, call the guy down the street to fix fans. Education is part of it. How do you education all of the people to the lowest level

Can you elaborate on how important government incentives are?

Government incentive has been a part of it, but it is not a major part. The stick is the building codes (new buildings and large renovations). Non government buildings follow LEED (from the United States) and the local one is BEAM. BEAM is now extending to cover renovations, but these are not government. Need the carrot, government is handing out money (subsidies) to replace old systems with new ones like changing the lights and installing more energy efficient motors, this has a partial effect. What we need is to give people who pay for this more incentive to save energy. It I need less money than before to do this. Sometimes you need a lot more money. Ex single pane to double pane windows is expensive. Big range in terms of energy efficiency that can be done. The government policy does not intervene in the market, they let the market sort out itself. The lower levels are up to the owners, the people who pay for the project to think about it.

Are there any other technologies you recommend we look into or any more advice you have?
Every component in the building has to be looked into. It is not just what you can measure with your meter. For example the windows, the sun is coming in and will heat up and need more AC. ASHRAE have been more proactive with AC design standards (90 I think) they have been incorporating more components (non air conditioning) in standard like windows, walls, roofs. They need to be integrated approach. Where one component will affect another component.

Questionnaire

Follow-up:
He will provide us with further information (if he can find it) to use his office as a case study: spec sheets, lighting design process and information such as spec sheets, spec sheets for sensors, spec sheets for air conditioner, etc. Additionally data sheets on technologies that Company M develops.
We also did a design for the AC that is quite different; we changed some of the fan coils to variable speeds with central control unit.
With normal tubes you have lighting coming off whole tube, not on the end, dark alley between two tubes. Our light has a reflector and diffuser to get more even surface
Spec sheets for sensor they use. Use different one in warehouse (also has daylight sensor) .
Unconventional design: separate air conditioning units for latent and sensible heat. Direct outside air systems. There are products of Europe and America, that do not work well in Hong Kong because of the humidity. Ex: Chilled beams were not good in previous office because it did not remove the humidity. Information on new fan coils.

After the interview, we got a tour of some of the technologies in his office.

Post-Interview Questionnaire C

Interviewee 16
Company M

Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (Mark with X):

List of technologies	Supply	Develop	Neither Supply nor Develop
Lighting Systems			
LEDs			X
T5 Fluorescent Lamps			X
Light Emitting Capacitor (LEC) Exit Signs		X	
Room Occupancy Sensor			X
Daylighting Sensors			X
Air Conditioning			
Chilled Beams			X
Oil Free Chillers			X
Variable Speed Air Conditioning	X		
Variable Flow Control for Condensing Water Pipes	X		
Air Source Heat Pumps			X
Water Source Heat Pumps			X
Electrical Installations			
Varying Fans and Motors	X		
EC Plug Fans		X	
Smart Meters to Track Energy Usage		X	
Sensor-based, Demand-controlled Devices		X	
Lifts and Escalators			
Linear Synchronous Motors			X
Regenerative Braking			X
Service On Demand Escalators			X
Elevator Destination Control Systems			X
Performance-based Approach			
Task Lighting Design			X

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

-

Please list technologies that you develop/supply that you can provide us with data sheets on:

-

Please list any case studies of the installation of specific technologies or general energy efficiency retrofits you can provide information for:

- I also attached the Zumtobel lighting design where we achieve desk surface light levels of 350 lux and above. For this zone it is 42 luminaires for an area of 255 square meters. Each Zumtobel luminaire is 51Watts so lighting energy is 8.4 W/SM or 0.8W/SF. Conventional lighting units will need 64 pcs X 108W/ea = 27W/SM which is 3 times more. For our office of 600SM the total savings on lighting power is 11kW, that is saving air conditioning energy too. We also use motion sensors to switch off some lights when not needed.

For each technology supplied or developed by your company, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology _Variable Speed ECM Fan Coil Unit with Individual Outlet Control:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- High level of comfort for each individual zone. Great reduction in energy consumption against dampered supply air ducts. EC motor savings on energy consumption.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- 10 FCU serving 20 zones cost including installation USD20,000 serving total floor area of 3,000SF. The installation cost was on the high side as this was a retrofit so there are costs involved with dismantling old FCU, rerouting some CW pipes, and slower progress.

What are the savings (if any) recorded over time in both monetary and energy terms?

- Comfort was raised for those sitting near windows facing west where summer afternoons cause heat stress. Did not measure individual FCU energy consumption but should be much better than fixed speed permanent capacitor motor that is standard in FCU.

How easy is it to integrate this product into an existing building and to install this product into a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- ECM are more expensive than PCM. The FCU also has a CHW valve control package to control exact water flow rate fed into FCU. So the total costs are much higher than normal FCU. Price will be a tall barrier.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- There are a number of ECM FCU in the market but occupies only a minute fraction of the volume. Price may be a barrier to these too. Clients who choose ECM FCU are those who own the building and pays for the energy bills. There is a payback but is rather long.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

-

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Ceiling void height and space may be restrictive on using these FCU. Since it can go up to 5 zones the unit can be very wide. Cluttered ceiling with lots of service piping and conduits may get in the way.

Additional Information or Comments:

- http://www.abilityprojects.com/ website of the FCU manufacturer.

(Please copy and paste the following sections as needed for additional technologies)

For technology Chilled/Hot Water Control Valves:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- FCU and hot water coils get exact flow rate with a modulating valve that also measures the flow through the valve. By preventing overshooting or bad valve authority comfort is raised and energy saved. As the valves can be controlled from central location there is no need to do valve commissioning and scheduling is easy.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

-

What are the savings (if any) recorded over time in both monetary and energy terms?

-

How easy is it to integrate this product into an existing building and to how easy is it to install this product in a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- It is not easy to integrate into existing buildings as facility managers tend not to change existing valves.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- It is not popular in Hong Kong. The market for pressure independent coil valves is still small, as most use on/off valves.

What (if any) potential and or known drawbacks are there to *using* this technology in new and/or existing buildings?

- No know drawbacks.

What (if any) barriers exist to the *installation* of this technology in a new and/or existing building?

- Additional cost of LAN.

Additional Information or Comments:

-

C.14 Interviewee 17

Interviewee ID: 17
Company ID: N
Category: Technology Developer/Supplier
Audio Recording: Yes
Duration: 20 minutes
Other Attendee: Colleague 17
Interviewer: Thomas
Scribe: Rebecca
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Gave intro and disclaimer
[We focus] mainly green building materials and specifically for energy efficiency we are the sole distributor of 3M commercial HVAC filter in Hong Kong and Macau. This filter has very low pressure drop compared with traditional mechanical filter. It has a high potential of energy savings.
Some other building materials like this for ceiling [showed sample model it has aluminum and is easily recyclable but it does not relate to energy efficiency, but green material. Also, we are selling the electric brushless motor, higher efficiency.

Positions
Colleague 17: *Interviewee 17 is the Executive director, I am the administrative director.*

Other than the ones you mentioned, are there devices you recommend in terms of energy efficiency and cost efficiency, specifically with air conditioning, lights, and sensors?
We are also selling LED light. And 3M filter. These are the two main products. And also, the DC specialized motor.

What are barriers to clients implementing the technology you have discussed and other technologies offered on the market?
In Hong Kong it is the culture. Ex. the 3M filter for ex, the client is very easy to switch from traditional mechanical filter to 3M filter. Can achieve about 50% energy savings. When we

promote we sometimes offer free trial because some customers may not believe it has such high efficiency. Even with the free trial some customers are reluctant. I think it is the culture, they are not easy to try something new. 3M filter launched to the Hong Kong Market a year and a half ago, Client 17a and Client 17b are the only two main customers. Some others are trying. Second barrier is many customers do not want to invest because the cost of 3M filter is more than the traditional filter. They can save the additional costs from energy saving within 4 or 5 months, but they are not keen to try it.

Do you think that the government can assist in getting some of these technologies into buildings?
I think Hong Kong government doesn't want to get too much involvement, They set their own government, but they do not impose targets on the commercial sectors. If the companies have their own target they a purpose to do energy saving. Try keeping system. The government does not have too much influence in Hong Kong.

What are ways that people can get more informed about the products available?
In today's Internet world it is easy to get the information about products. The problem is if they are willing to try or willing to invest. They need to invest before they can save the costs. There is a lot of ways to get this information on website, seminar, many ways to get this information.

Case studies?
We have the data from those two buildings that use 3M filters. They tried the filters for almost one year, they recorded it by themselves and sent it to us. We know the filter performs with about 50% energy savings.
Colleague 17: *We can send it to you in an email. Can also email catalogue.*

Questionnaire
Ok
So what is the purpose of this?
If the government can subsidize the projects, customers will chose to use these. Incentives in terms of money.
Retrofit is not easy. 3M filter is easy to swap.

Post-Interview Questionnaire C

Interviewee 17
Company N
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this

questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (Mark with X):

List of technologies	Supply	Develop	Neither Supply nor Develop
Lighting Systems			
LEDs	X		
T5 Fluorescent Lamps	X		
Light Emitting Capacitor (LEC) Exit Signs	X		
Room Occupancy Sensor	X		
Daylighting Sensors	X		
Air Conditioning			
Chilled Beams			
Oil Free Chillers			
Variable Speed Air Conditioning	X		
Variable Flow Control for Condensing Water Pipes			
Air Source Heat Pumps			
Water Source Heat Pumps			
Electrical Installations			
Varying Fans and Motors			
EC Plug Fans	X		
Smart Meters to Track Energy Usage			
Sensor-based, Demand-controlled Devices			
Lifts and Escalators			
Linear Synchronous Motors			
Regenerative Braking			
Service On Demand Escalators			
Elevator Destination Control Systems			
Performance-based Approach			
Task Lighting Design			

Please list any other energy saving technologies not listed in the categories above that you use or might consider using in your buildings:

-

Please list technologies that you develop/supply that you can provide us with data sheets on:

- 3M Commercial HVAC Filter

For each technology supplied or developed by your company, please type in information under each question to the best of your ability. Answer spaces are marked with the '■' bullet points:

For technology_of electrostatically charged synthetic media HVAC Filter:
What are the benefits of using this technology for both new construction and retrofitting buildings?

- Low pressure drop for potential energy savings (lower energy consumption)
- Long filter life (reduced waste disposal volume & labour cost)
- Factory installed gaskets for consistent reduction of air bypass
- Simple, hassle-free installation without clips
- 100% metal free and fully incinerable
- 100% synthetic, which moisture and humidity resistant
- Lightweight frame construction
- Reverse flow options are also available

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Just air filter replacement cost

What are the savings (if any) recorded over time in both monetary and energy terms?

- When comparing with the conventional filter, Cost Saving for 3M Commercial HVAC Filter at AHU motor is more than 15%.

How easy is it to integrate this product into an existing building and to install this product into a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- It is pretty easy to integrate the filter into either an existing building or a new building. The barrier will probably be higher initial cost and ignorance in potential energy saving that can be achieved by using the filter.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- It is not popular at this moment. Only a very small proportion of clients concern the energy saving potential of air filters.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- No drawback.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Higher initial costs.

Additional Information or Comments:

-

(Please copy and paste the following sections as needed for additional technologies)

For technology_of EC Plug Fan:

What are the benefits of using this technology for both new construction and retrofitting buildings?

- Higher efficiency, lesser maintenance, lower running noise, higher reliability

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Depend on the size. In general, it is around HK$ 300,000 per retrofit of one Air handling unit.

What are the savings (if any) recorded over time in both monetary and energy terms?

- About 50% - 60% saving in annual energy cost of an air handling unit

How easy is it to integrate this product into an existing building and to how easy is it to install this product in a new building? What are some barriers (real or perceived) to installing and utilizing this technology? Please explain your answer.

- It takes about 2 days to retrofit an air handling unit of an existing building. The work include taking down the existing centrifugal fan, motor and inverter and having them replaced by EC plug fans.
- It is easy to install at air handling units of new building. The fans are installed by the AHU manufacturer, dismantled and reassembled at site.
- The barrier is probably higher initial cost and clients' reluctance to early replace the fans that are still working.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology? What proportion of clients choose to use this technology compared to other technologies?

- Getting more popular but still a small portion of clients choose to use this technology particularly in retrofit work,

What (if any) potential and or known drawbacks are there to *using* this technology in new and/or existing buildings?

- No drawback compared with traditional AC fan.

What (if any) barriers exist to the *installation* of this technology in a new and/or existing building?

- Higher initial costs particular for existing building that require modification of the air handling unit.

Additional Information or Comments:

-

C.15 Interviewee 18

Interviewee ID: 18
Company ID: O
Audio Recording Allowed: Yes
Duration: 1 hour
Interviewer: Thomas
Scribe: Rebecca
Notes Compiled by Rebecca

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Introduction by Thomas

Are there any devices that you recommend for building energy efficiency retrofits?
There are 3 basic elements. First: The clients' needs are important and the type of building they are serving. For example, high end clients do not care as much about energy efficient. Second: the operation mode of the building. If it operates 24 hours a day, energy efficiency is important. Third: Prestige level of energy devices they are looking for.
Above all, the control plays an important part. For example, if you use an energy saving chiller, but the control is a mess, it is like driving a fuel saving car always in high revolution. Control plays an important part: regarding sensors and controllers. The accuracy of sensors and controllers is another critical factor. The accuracy for normal controls will be +/-- 5%, this affects immediate response.

If they are asking to lower energy efficiency in office building that operates during business hours for example, what are typical technologies you recommend in lighting and air condition? And do they have control over this?
Two categories: hardware and software:
Hardware: lighting and AC units. Most of the people are aware of the energy efficiency hardware available on the market, i.e. LED. They [LED and AC] are basic and essential can save up to 25-30% by changing luminaires compared with non energy saving ones[fill in]
Software: How to control. For example, and office with working area and conference rooms using conventional light switches. In this office the work space is lit all day, but people will be working in the conference room. Working maybe 9 hours a day the workspace light will be on for

9 hours, but half of the time will be in the conference room with those lights additionally on. They can get energy saving if the light turns off in the workspace. Control is an important aspect. Highly recommend the client to tell me what the operation habit is so we can fit in certain parts of the automatic control. Human behavior is the most difficult part. I cannot ask the end users to change habits, it is very difficult to change. It is different if we use automatic control to regular the energy efficiency. A motion sensor for the office ex, the light and AC in the unused area can be turned off. It is very difficult to convince the client to adapt because you have to pay a bit extra at the beginning, people do not want to invest the extra. A payback period of 5 is acceptable, less than I am more than happy, and over 5 years need to review. It is ultimately up to the client. If they are only in the space for 3 years, so they will not bother to take payback of over 3 years [when retrofitting]. There are a lot of factors to consider.

Do you think that government incentives will assist in motivating the client?
Yes it [government regulations]will be very important. We have been talking about global warming for past 10-15 years, but it still seems distant to many people, people will focus on ROI (return on investment), CSL (government requirement in 2015, every stock listed company on HK, have to include a sustainability report in their annual report) This helps for major stock listed companies, but for small/medium that are not stock listed yet, it seems far away to them. Government can help boosting the energy saving sense for medium and small. Most medium and small size developers want a quick ROI, by buying and selling quickly. They get great return on the selling the buildings and do not have incentive to make energy efficiency because they will sell. If there is not government policy, they will continue to do that. There are more buildings that are not energy efficiency enough. If you are going to introduce policy, developers will be against it. Government incentives to help and improve the sense of energy efficiency investment and will help medium and small developers to improve energy efficiency of buildings to make basic elements energy efficiency for future energy efficiency saving.
Government policy paired with government incentive is very critical. For example, BEAM+ , the government in 2010 (check year) they introduced a policy and incentive: By being BEAM certified, you can get an extra 10% GFA. This is a huge factor because land premium is expensive in HK. This enables a lot buildings by BEAM + there are more than 1000 buildings being assessed, 275 buildings have been assessed [go to website to find numbers]. Government policy and incentives have to go in a pair. To impose a policy, there will be a lot of people against it in the legislature and incentives will help to pass.

Can you tell us more about BEAM+ for existing buildings and the success of this program so far?
Just launched last year, we still need more momentum in HK to get existing buildings to be upgraded. The majority of buildings were built in 1980s/90s. There is something to be done: old equipment to be replaced; there will be a lot of implementation that can be carried out. Energy efficient lighting and cooler can be replaced easily; there are a lot of other items, control

behavior that can be implemented. The new version of BEAM+, the latest version is more easily adaptable, you can declare a certain portion to be certified. It still needs a long way to go. I am glad they have launched BEAM+ for existing buildings. We [Hong Kong Green Building Council] are introducing new schemes to meet with the correct situation to implement different things such as launching education program, government policy, to ensure positive way.

C.16 Interviewee 19

Interviewee ID: 19
Company IDs: P1, P2, P3, P4
Category: Technology Developer/Supplier
Audio Recording allowed: Yes
Duration: 1 hour and 30 minutes
Interviewers: Nikhil and Jonathan
Scribes: Cameron
Notes Compiled by Cameron

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

[Nikhil introduces the script:]
I've been in the technology R and D department. Develps from lab to commercial.tech is changing and advancing today. People today are always seeing innovations.
Everything we will be talking about today is available to the market. We are ready whenever you want to publicize the material. Some of the ideas I will show later are very original, however.
If i had these worries [giving info confidential] I wouldn't be doing the interview. After the interview, you have to take time to think about it. I am happy to meet you, and happy to share. I like it when new things come up. Especially in energy efficiency.

Maya: we'll leave it to them, but I will talk to them later. They'll write it all down. Jonathan will stay. I'll take the card.

[Nikhil gives Disclaimer:]
Yes, Yes, you may record.

[Nikhil goes over what we know.] Is there anything you would like to add?
You've covered part of the Company P1's business. Building and Energy are two key words. Analytics is the third. We do not use analysis, because we think that
We do building energy business. Started about four years ago. We do have a new government regulation. Almost all buildings in HK have to go through energy audits. We carry out energy audit activities. We then hope we can use analytics with the data we collect with audits. But now is not the time for that. Expenses are low. We have almost done 10,000 buildings' energy audits

for Hong Kong. with this database, we start to look into it. But we still do not start analysis. No analytics yet.

Anything else?

You have almost covered my profile. I am the founder of these companies. We carry ambitions as of five years ago. Company P2 will grow. Now effective mechanisms to measure carbon emissions. We still look positively that Company P2 can be a good mechanism. And we are right. We found in china, that Company P2 started five years ago. We are hoping that it will carry on. I look forward to Company P2 happening in Hong Kong. currently, there are no policies which will help Company P2 in Hong Kong. these do exchange in China however. They help lower carbon emissions, by taking money they gain and investing them in new technology. We have to go further to make it happen in Hong Kong.

As a company however, we have to survive. four years ago, government launched first energy efficiency policy in buildings. We were established to tackle this policy, and try and make commercial value in this. This is the story of BES and Company P1. we are not satisfied with this.. We don't think this is enough. As a building owner, you want to have something helping. Three years ago we opened a solution provider company. You can call it a solution provider.

What was the name of the third company?

After a few Company P1 operations years, we send them this card [hands card]. After progressive development of energy efficiency market, people are no longer satisfied with consultancy. "Can you cut my usage to 20% in two years?" they want results. I am not just a supplier. This is my goal. To make it a total solution provider company. [card says Company P3, Tony is Director]. If i cannot provide, i can connect people. And become a platform, if buildings are unique. After three years. I still find it not satisfactory. Such as LEDs.

100% of LED market, we have only 20% done. We have a big gap to fill. I know LED will be treend though. When market share is mature, what will it be? I know LED will eventually become norm. I have to look at tomorrow's solution. Two years ago I started another company, focusing on technology development. To see tomorrow's solutions. I do invest in some R and D, with local universities. Today I will have something to show you. It can be applied and accepted in the future, I believe. This company is called Company P4.

For sake of today's interview, I want to share. You still have a lot of chance to change the world. Eventually helping the world mitigate its environmental impact, will not be a one generational project.

What are your majors? Architectural?

Nikhil: ECE and CS/Robotics

Yes, computing is very important. When I face the running of my business using a mobile app... your expertise can help. Everyone is talking about data use. I do believe that in a city, you will want it to operate effectively, and to do this you need to rely on data. I slowly step in the development of 'smart city'. Environmental issue can be solved with a good management system. You cannot rely on people, you have to manage them. A lot of tech does not work efficiently, because people aren't effectively using it.
In Hong Kong I have some participation in smart cities. First off, you must focus on the big picture. No one has the capability to manage all of the people in Hong Kong. the Smart city is a mega trend in the world. Cities are competing with each other. They are changing the ecology of an entire city this way. IT helps.

Why is Energy Efficiency so important?
Because of the people who want it. Efficiency is not important, if you have money to spend. I think it is subject to the people who are paying. But if you have a policy, it becomes mandatory.

Government does have Building Energy Codes. How useful are they do you think?
Codes apply to all kinds of buildings. We have done a lot of energy audits in Hong Kong. but government also stated that whenever there will be a major retrofit, you have to comply to codes. This is mandatory. You have to comply with the regulations.

Speaking of retrofits, do codes act as a barrier to retrofits?
Not the right question. When you are going to retrofit a mall, the driving force may be because mall is too old or you want to beautify it. This should be the first driving factor. First you have to change something. You first have to replace lighting, escalator, AC. when these changes in facility happen, they have to comply to these laws. The owners are hesitant to comply.
ex) famous retailer used to have old design for interior lighting. Stick to old design very consuming energy. With codes, they cannot use tungsten or halogen light bulbs anymore. They have to now consider that they will be subject to fines, and to prosecution. Now operators have to comply. This is a matter of the gov't. Matter of time, when situation becomes very normal, and everyone is used to it, it will become a very lateral practice.

For LEDs, up to 20% of lights are LEDS. what would help their market grow?
The market is growing. It will grow even faster in the next few years, due to the codes. If you choose to use T8 or T5, you are not complying to the codes. LEDs must be used now. One day, you will start considering the new one. The way the price is dropping, you will eventually be making an easy choice. In about four years, I expect 80% of lighting will be LEDs. we have to start thinking: what is next?
The latest one is 2015 version. Code requirements, are now changing. They will see if there is new tech coming. If a new one comes along, they will have to begin making it regulation.

According to new codes, you have to do more data sensing (2015), ie. daylight, occupancy sensors. This is a step forward. Fill the gaps before new technologies come into place.

You talk about sensors, and gov't. do you think if they gave incentives to subsidize the price of LEDs, would that help increase the development of new technologies?
We did this before. They tried to subsidize Energy saving technology. Now it does not have subsidizing means. They have other kinds of indirect subsidization. About two months ago, we had the policy to let those who run a small or medium business, where gov't will cover certain technology retrofits with vouchers of technology. Will subsidize 50% of their installation costs. This is new.
Gov't doesn't actively do this. They want market to adjust, not be too involved in the market. These codes are only two months ago.

How important are meters, as you mentioned?
You are IT guy right? Currently they are trying to make use of building management system to optimize the building efficiency. HK is often behind. They sometimes think new technology won't be good for them. They like to maintain the old style of working. This is very basic and simple. Metering becomes a very important element. Five years ago, I put metering as one of the elements in my company, and it happens now, after five years. They are very remarkable contents about energy management and monitoring. Trends are changing, and price of meters are dropping. People will eventually make better use of the information they are collecting.

You mentioned one is a lot of building owners don't want to include meters or new tech. tech price going down will improve the issue. Any other barriers?
Yes. If you originally put master meter, but you then want to add more? You have to rework your system. Budgeting is also an issue. If people think it is more lateral for them to put budgets on metering… metering may be one of the first things on an agenda, and on a budget soon. In the future, energy efficiency may rely on budgeting, not on technology.
IOT [wireless Information of Things, uses wireless metering stretegies to create a 'smart grid' system] becomes a very important element. There is already metering technology. You need new technology to be differentiable. We need to change our strategy in metering businesses by putting IOT in it.

As you mentioned, some old meters have been installed, if the gov't would inform the population about these meters, would this help in the adoption of these?
When you are talking about meters there are two markets.
One is the utility market, mastered by the government. The other is the commercial market. Each has their own way of handling it. Utility market is easy, because you just get the government to change.

You can see the beauty of a smart metering network. Most likely we won't start in Hong Kong. They will tell you reasons why not, we already have some ideas to solve this. This is still an issue the gov't has to face. HK will not be the first place to start.

We are also collecting case studies. Any stories you would like to mention?
Meters have two sides of business. One is the trading side. We send meters to customers. The other is providing solutions.
We have a project in Macau, where they have a complicated AC operation with chilled water supply. They want to manage it. They don't know where the energy goes. They want to manage it. So they built a very huge metering system. Now they have data on hand, and can easily do analysis, and know where energy goes. They can easily find out if there will be any issues with the system. After some time, they may incorporate a self learning information system throughout the building. We are still working on it, of course. It starts with metering. It starts with one simple solution.

Jonathan: Current situation in the uptake level? broadly of different technology types. What is the uptake level? Can you list out some technologies which are commonly used, and some which are not commonly used?
Simply, we believe tech is something new. This is not correct. Some may be very old. I can tell you the supplier controls the situation. They provide good prices and specific technologies. Sometimes the money issue is a very important factor. In US, you have a better way of calculating Return on Investment. In Hong Kong, we do not have that.
In Hong Kong, for example, LED is a simple solution. But a lot of people still hesitate to use it. In the metro station next door, they are still using T5 or T8. Why? No really, why? They have a choice.
The suppliers of the T5 or T8's are the ones who control that situation. That cannot be avoided. If you're an employer, the budget is a very big issue.
People in Hong Kong are looking for a short return. They do not have the culture in Hong Kong, to promote new habits and technology. We save energy by investments. Investment terms must be definable to persuade someone to use your technology. We are more often the promoter because of this. This is, I thought, the biggest challenge. At least the government does something to influence the market.
I think you will see in the coming few years, a new policy in climate change. People will start to think about lease… for example WWF, the earth hour program. At first, the program only asked for fifteen minutes to turn off the lights. That night, only a few buildings joined. Now, it is each hour, so a full hour. Now, no building will not join. If you don't join some energy trends, it can be headlines the next morning. In this case, it is the community who creates the change. Not the government.
I have been working on a project, recently. Gov't organized a competition on energy saving. There are almost 300 participants. I read all of their forms because I am behind in charge of

doing this, and assessing. Many companies, with big names, will use any of these technologies. Some are even promoting new technologies. I see the change. They begin treating energy efficiency as corporate risk management, not just as an investment of money and cost. If you don't do something, then you are behind. If you don't get an award, you are not needed. They treat this as a kind of business risk management.

Jonathan: risk management with government? Are certain technologies standing out?
I think the Government is already doing a good job. If you refer to the website, like EMSD, you see a lot of suggestions there. They call it EMO (energy management opportunities). With three categories.
Low investment
No investment
Bank investment
No one starts with bank investment. They start with simple management measures, such as keeping light switches off. This is No investment, or no cost at all. You start here, and soon your savings may become a budget for you to use the next year for a low investment, such as a motion sensors instead of light switch training. What's next? The new technology. Such as LEDs. or an energy retrofit for your building. The cycle gets more positive.

Jonathan: we are interested in collecting case studies. It would be particularly helpful if there were particular examples of stories with numbers?
For this case studies, I can share with you some. But, you are looking for a very remarkable one or typical one?

Jonathan: we welcome all studies.

In HK we have some big projects done. But in HK, situation is very typical. A lot of commercial buildings. office towers and hotel buildings. All using central chillers. In the old days we used the air coolant on the rooftop, with the air to cool down. We call it heat cool. In Hong Kong, we use water cool. Water is more effective. We try to adopt water cool instead of air cool. People believe that by changing from air cool to water cool, that savings can be huge, and the payback will be short. Now we can share this. The tech is not so new. But the way to do it is new, because people in Hong Kong have been more receptive to it. Just because of the budgeting issue. I believe that in the next three years, there will be a lot more changes to water cooling. Even though we have the mild weather, we still like to have the air conditioning. The practice in Hong Kong is very unique. It is a matter of habit. We change our behavior, then technology, and eventually, we will be able to save energy.

We also have a questionnaire to show you [shows questionnaire] If you would like to talk about them now, that's fine. If not, we will send them to you.

You are using 'state of the art' tech. most of them can be grouped. People are changing their minds. With more scientists joining the circle of mitigating environmental issues, some of the new ideas come from more than engineers. From chemistry, biotech, any of these disciplines can be put into new technology. You may know solar panels, but the technology originally came from physicists. Hong Kong i can see the drive technology is pure engineering. Tomorrow it may be IT, or material science. The same is true for buildings. We used to use construction for choosing our building materials. Now we ask people from science and technology backgrounds.
I have brought along my material of what I am doing: both material based solution. One is façade treatment called Sun Zero. The other is an optical coating for lamps, which can increase light output, enhance light quality, and improve energy efficiency by requiring less powerful lights to provide the same amount of lumens. It applies to all lights, not just lamps.
One more thing we are doing: we can have lamp mate lasting for ten years. If using traditional metallic one, UV will age your reflecting surface. It will oxidize very easily. A simple solution can help. These are the highlights for this year. These are the material based technologies we are promoting.

Jonathan: thank you for bringing these samples. Nikhil and Cameron will follow up with questionnaires. If possible could you provide us with case studies as well.

Is there anything you would like to ask?

C.17 Interviewee 21

Interviewee ID: 21
Company ID: R
Category: Technology Developer/Supplier
Audio Recording Allowed: Yes
Duration: 45 Minutes
Interviewer: Cameron
Scribe: Nikhil
Notes Compiled by Nikhil

These notes have been modified to ensure the confidentiality of the interviewee and company. All responses are representative of his/her views and not of his/her company

Questions
Responses

Our idea of company, is there anything you would like to add?
We are global specialist in global energy and management. We do not do any power generation and no appliances but we do everything in between. So the major part is power distribution from medium voltage to low voltage. Buildings and up to the MCB boards. Lighting switches and controls for any appliances. In automation, we have building management system, lighting controls, control sensing, and security control. In terms of energy, we have automation at the back end like power quality management, harmonic filter, etc.
We have another business in industries for process control PLC, solutions for industry business. In the IT division, we don't have servers but we provide mainly from the APC grid from the US that we acquired. So we have everything in between power generation up to the user.
For providing energy monitoring, we have meter, software and all these types of solutions with monitoring and control. Our company focuses on energy management and fighting climate change. However, we do not have any renewable energy but we do have renewable interface. We help customers understand how they use their energy and how turning something on or off makes a difference. We do this with the help of sensors.

Why is energy efficiency important to your company?
I believe that it is the group direction. The two main things are helping developing countries to gain access to energy but to the rest of the world, we are a part of the society dealing with climate change. Some research says that energy use will be doubled in a 2 or 4 years due to urbanization and the increase in population. We need to reduce CO2 by half to stop global warming. We need to be 3 times more efficient. Renewable is unable to catch up but then we are

a part of the technology that can improve efficiency. That's what we do and that's the concept that the CEO introduced and that the DNA of the company.

Is there a certain sector that needs to be looked on when looking to reduce the energy use in Hong Kong?
Commercial buildings are the main part of Hong Kong. Apart from residential buildings, there are mainly commercial buildings and we see a lot of potential here. An example is centralized air conditioning. Normally, your management handles your air conditioning and so there are no incentive to save from this because it's the same price. It's too cold a lot of time in malls and commercial buildings. In Hong Kong, air conditioner is the major energy user and so there is a lot of potential for savings.
At the back end, whether the chiller is the latest, and your chiller control also helps. Combining the chilling system and usage by tenants has a lot of potential. LED lights are very common and energy saving is lower.

Are there any key incentives that your provide customers for making changes?
We are not providing incentives to customer but give them options. We give them solutions that will give the benefit to either the tenant or themselves. They look at the return on investment but the challenge is that electricity is not very expensive. So that payback from saving on electricity is not much and so payback period will be longer.
Big companies have a target from their property sustainability group commitment. They may not receive a huge return on investment but they use the investment to reduce their carbon footprint.

Are there any key technologies that you generally recommend?
Meters are certainly very important. Hong Kong get recommendation from the Building Energy Code but it is not enough. The data is not sufficient to monitor energy usage.
Challenges in existing buildings is that operation cannot simply be stopped to retrofit and there is no space for meters. Current transformer is outside and our meter is wireless and thus, the cost of the retrofit is reduced.
The latest meter is called Power tech which came out last year. It is a small device that is put on MCB. Measures power, current, voltage and with the receiver nearby, the cost reduces. Thus we can enable low cost solution. Thus, you can find out the energy used by lighting, air conditioning and so on in a certain area. With this monitoring, people will change their behavior.
We have software applications as well. One of our projects in the Hong Kong Science park, we have solutions where property managers can login to see data on the entire building while tenants can login to see data on their floor.

Are there any types of Air Conditioner that you generally recommend?
We have Oil free chiller. We have them installed in BEC building and will install another in the retrofit project as well. They have a high efficiency. In Hong Kong, they have already been

accepted. Hotels, hospitals, school already use or are considering using Oil Free Chillers when considering retrofitting when the existing chiller is reaching its end. They were more expensive but are coming down. They have a higher capital investment but they also have a higher payback.

What barriers are the most common when dealing with retrofitting?

Return on Investment not easy. Another problem when dealing with energy monitoring, there is no direct saving. The result depends on how you use your energy. There is no scientific calculation. Information is required and monitoring helps.

It depends on how business operators look at performance. My company spends a higher capital expense and spend less on operational expense while many tend to do the opposite. Companies look at their business in a short term. They need to have at least a 10-year life cycle in mind or else they will use technology that is meant for the short term. The lifecycle justification helps because it shows that changing technology every 4 to 5 years wastes money.

Any particular story about successful retrofits with clients?

Science park is one case. In another, we started persuading companies. We have another solution called [] where you simply put it in your kitchen and install the sensor at the MCB and then find answers to usage through an application on your mobile. It should be in use in Hong Kong soon. There is a low capital investment to tenant. Thus, it will become quite popular in Hong Kong. When tenants talk to the building owner about this, they will also be aware of the importance of energy monitoring.

Another successful installation is of control systems for Company C properties where we can get the information of the air conditioner and light sensors. However, it is difficult to predict how many people use a certain area due to it being a rented property but it controls the lights and cooling systems depending on the number of people.

For hotels, control systems are already being used where lights as well as the air conditioner are turned on when the guest enters the room and is turned off when he leaves the room.

Questionnaire – do any of these technologies look familiar to you?

LED are often recommended but were more expensive but now, they are used more often.

We recommend Oil free chiller and have variable speed air conditioner.

For the heat pump, it really depends on the application. They are needed when you have a heating and cooling requirement. In hotels and hospitals, hot water is needed and for those cases, heat pumps are recommended.

We do not supply chilled beams but they are used in some offices

Post-Interview Questionnaire B

Interviewee 21
Company R
Thank you for agreeing to fill out this questionnaire. Please answer the questions to the best of your ability. Feel free to write any information you think could be helpful. Any and all information you put down will be helpful to the completion of our project. All information in this questionnaire will be anonymous in our analysis and reporting.

Please indicate the best answer for each energy saving technology listed below (mark with X):

List of technologies	Recommend to Clients Mark "Often" or "Sometimes"	Never Recommend to Clients	Unfamiliar with
Lighting Systems			
LEDs	Neutral		
T5 Fluorescent Lamps	Neutral		
Light Emitting Capacitor (LEC) Exit Signs	Neutral		
Room Occupancy Sensor	Often		
Daylighting Sensors	Often		
Air Conditioning			
Chilled Beams	Neutral		
Oil Free Chillers	Neutral		
Variable Speed Air Conditioning	Often		
Variable Flow Control for Condensing Water Pipes	Often		
Air Source Heat Pumps	Neutral		
Water Source Heat Pumps	Neutral		
Electrical Installations			
Varying Fans and Motors	Often		
EC Plug Fans	Often		
Smart Meters to Track Energy Usage	Often		
Sensor-based, Demand-controlled Devices	Often		
Lifts and Escalators			
Linear Synchronous Motors	Neutral		
Regenerative Braking	Neutral		
Service On Demand Escalators	Neutral		
Elevator Destination Control Systems	Neutral		
Performance-based Approach			
Task Lighting Design	Neutral		

We are "supplier" and in the above, we only "sell" our products to customers. For others, we are “neutral”.

Please list any other energy saving technologies not listed in the categories above that you recommend to your clients:

- Building Analytics (to monitor each major equipment performance, give alarm/alert if the efficiency or COP drops to a certain level. Like chiller COP and filter clog of AHU/PAU)
- Demand Control Ventilation (using means to measure the number of people or CO2 level inside a room and control the fresh air quantities, not to over-provide to save energy)
- Close monitoring of final circuit energy consumption and benchmarking with similar rooms or facilities and give alert/alarm to aware Energy Manager to take necessary action.
- Expertized Room Control utilizing mini-BMS by utilizing motion detection, photosensors, dimming, resetting of room air temperature to provide air-conditioning and lighting only when there is occupancy and also provide daylight harvesting. All these will comply with the BEEO requirements.
- PQMS to ensure harmonics level is kept to an acceptable range which would not cause heating up of the cables like the limiting of neutral current. Also cures the power factor to avoid too much virtual load.

Please list any case studies of the installation of specific technologies or general energy efficiency retrofits you can provide information for:

-

For each technology recommended to your clients, please type in information under each question to the best of your ability. Answer spaces are marked with the ‘■’ bullet points:

For technology_ Building Analytics_______:

What are your reasons for recommending/suggesting this technology?

- **Direct energy saving.**

What are the benefits of using this technology?

- **Direct monitoring of performance of each major equipment to make sure their performance is optimized to save energy.**

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- **Depends on situations. For systems already have meters and sensors in the BMS, the software only costs for $100,000 to $200,000.**

What are the savings (if any) recorded over time in both monetary and energy terms?

- **Normally up to 20 or 30% of the individual equipment consumption.**

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- **Depends on situations. For systems already have meters and sensors in the BMS, the software is just added on and easy to deploy.**

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- **This has become more and more popular these few years in overseas. Hong Kong also have 5 to 10 cases.**

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- **Already 5 to 10 projects. Ranged from some small SME offices of 20,000 sq ft to large building block of total 2,000,000 sq ft.**

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- **Not found yet.**

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- **Customers' hesitation to invest.**

Additional Information or Comments:

- **This is a new trend to have more real-time monitoring and this will also ease the future retro-commissioning efforts.**

(Please copy and paste the following section as needed for additional technologies)

For technology_Demand Control Ventilation_______:

What are your reasons for recommending/suggesting this technology?

- **Fresh air treatment costs a lot of AC energy.**

What are the benefits of using this technology?

- **Save AC energy in treating the outside 33 degC air to 17 degC.**

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- **Minimal as only involve a CO2 sensor and a controller to control the damper with variable flow control. Costs around $100,000 for each PAU system.**

What are the savings (if any) recorded over time in both monetary and energy terms?

- **Around 10% of the total AC energy cost.**

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- **Just install a damper and a control box at the fresh air duct.**

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- **Very popular for large building.**

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- **Nearly 100% for large building but only minimum for e.g. classrooms. Could not tell the total sq ft of using this technology as the figure is large.**

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- **CO2 sensors needed to be calibrated but most FM team would not carry out calibration every year.**

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- **Not much barriers.**

Additional Information or Comments:

- **No more comments.**

(Please copy and paste the following section as needed for additional technologies)

For technology_ Close monitoring of final circuit consumption _______:

What are your reasons for recommending/suggesting this technology?

- **Final circuit consumption like the plugged load becomes more significant but most people ignore that in the past.**

What are the benefits of using this technology?

- **By monitoring the final circuit consumption, we could understand how much energy is used and could introduce control to limit this consumption, like automatically turning off the plugged load during the night time to avoid, say, computer monitors are at standby mode to waste energy.**

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- **Depending on situation, but in general, could be around $500 per MCB circuit.**

What are the savings (if any) recorded over time in both monetary and energy terms?

- **Standby consumption could be 8% of the equipment load.**

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- **Just simple modification at the MCB board.**

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- **No similar energy efficiency technologies.**

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- **This is rather new and up to now 5 projects only. Floor area around 500,000 sq ft.**

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- **No drawbacks as this is only monitoring.**

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- **No barriers on technology, may be initial costs.**

Additional Information or Comments:

-

(Please copy and paste the following section as needed for additional technologies)

For technology_ Expertized Room Control utilizing mini-BMS **_:**

What are your reasons for recommending/suggesting this technology?

- To comply BEEO of HK.

What are the benefits of using this technology?

- This saves energy.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Around $20,000 to $30,000 per room.

What are the savings (if any) recorded over time in both monetary and energy terms?

- 30% of the room energy consumption.

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- The system could be stand-alone and easy to install.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- This is new but becoming more and more popular.

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- So far many hotels have used that. More than 1,000,000 sq ft area.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Needed to by-pass the existing control.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- Installation of new room controls needs two or three days works.

Additional Information or Comments:

- **More information can be found from the following webpage:**

(Please copy and paste the following section as needed for additional technologies)

For technology_ Power Quality Management System **_:**

What are your reasons for recommending/suggesting this technology?

- To comply BEEO of HK.

What are the benefits of using this technology?

- This saves energy.

What is the initial installation cost for this technology? Per installed device and per square meter of the area where the device was installed?

- Range from $200,000 to $300,000 per building main circuit.

What are the savings (if any) recorded over time in both monetary and energy terms?

- Range from 3 to 10% of the total electricity load.

How easy is it to integrate this product in an existing building and to install this product in a new building? Please explain your answer.

- In new building, as no measurement data available, may have over compensation.

How popular is this technology in comparison with similar energy efficiency technologies? How widely used is this technology?

- Very popular as people now aware the Harmonics.

How many of your client's buildings use this product? What is the total floor area this technology in operating in?

- More than 70% of the buildings.

What (if any) potential and or known drawbacks are there to *using* this technology in new or existing buildings?

- Needed to take on-site measurement for sizing the compensation equipment.

What (if any) barriers exist to the *installation* of this technology in a new or existing building?

- May be initial costs.

Additional Information or Comments:

- No additional comments.

Appendix D Recommended Technologies

Disclaimer: The following list of 14 technologies contains data acquired from many sources, including interviewees, EMSD, and BEC. The data provided are intended to be used as examples. There are many different technologies from many different suppliers, and the data for each is relative to the specific devices provided by each technology supplier. In most cases, the cost and energy saving data are also relative to many other factors, such as a building's type, layout, electricity cost/kilowatt hour, traffic, etc. These factors are mentioned within the body of the list below. The information within the list is intended to provide managers with the guidelines to help them make knowledgeable decisions when planning retrofits to their buildings. Some information was not readily available to be included in this report. Much of the information not shown within the list can be found by analyzing either the rates of a building's electricity provider (i.e. cost savings) or the specific costs set by the technology supplier they intend to use in the retrofit (i.e. capital cost). In the end, it is up to the building managers to decide whether or not these technologies or practices are appropriate for their building.

<table>
<tr><th colspan="12">D.1 Lighting</th></tr>
<tr><td colspan="3">LED lights</td><td colspan="3">T5 fluorescent lights</td><td colspan="3">Room occupancy sensors</td><td colspan="3">Task lighting design</td></tr>
<tr><th colspan="12">D.2 Air Conditioning</th></tr>
<tr><td colspan="2">Oil-free chillers</td><td colspan="2">Variable speed drive (VSD air conditioning</td><td colspan="2">Variable flow control for condensing water pipes</td><td colspan="2">Heat pumps</td><td colspan="2">Variable speed drive (VSD) fans and motors</td><td colspan="2">Electronically commutated (EC) plug fans</td></tr>
<tr><th colspan="12">D.3 Lifts and Escalators</th></tr>
<tr><td colspan="3">Linear synchronous motor (LSM) lifts</td><td colspan="3">Regenerative braking lifts</td><td colspan="3">Lift destination control devices</td><td colspan="3">Service on demand (SOD) escalators</td></tr>
</table>

D.1 Lighting Systems

LED Lights	
Description: LED, or light emitting diode, is a semiconductor chip that emits electromagnetic waves or light when a voltage is supplied to it (EMSD, 2016a).	
Discussion: LED tube retrofitting varies, from being an easy replacement to requiring a small-scale retrofit, depending on the initial fluorescent fixture and whether it is being replaced or not. Certain LED tubes can fit into existing fluorescent fixtures, with almost no disruption to the building occupants, but is restricted to the limitations of the fluorescent fixture. This would be a viable retrofit to be done by either a tenant or building manager due to the ease. A more significant retrofit is required for LED tubes that require the fluorescent fixture to be changed or removed and some rewiring done. In this case, the best time to retrofit would be when a tenant moves out. This retrofit would be more viable for the building manager.	
Data: (Compared to T8 fluorescent bulbs) **Equipment cost:** $50-100 HKD per bulb **Installation cost:** $100 - 200 HKD per bulb (Interviewee 08) **Energy savings:** 30 to 50% (Interviewee 08) **Payback period:** 1-3 years (Interviewee 08)	**Advantages:** Long lifespan (50,000 hours) (Interviewee 08) Durable, no moving parts or glass bulb Come in different colors of light based on the material (EMSD, 2016k) Turning on and off does not affect the lifespan (Premier Lighting, 2015) **Disadvantages:** More expensive per bulb on average than fluorescent lighting (Interviewee 08) Compatibility issues with fluorescent fixtures (Premier Lighting, 2015)

<table>
<tr><th colspan="2">T5 Fluorescent Lights</th></tr>
<tr><td colspan="2">Description:
T5 lamps are the latest generation of fluorescent lights on the market. It offers a smaller size and greater efficiency than its predecessor, the T8 lamp. T5 fluorescent lamps achieve a 30 - 40% increase in efficiency when compared to T8 fluorescent lamps by increasing the frequency of the current in the light, while maintaining the same duty cycle.</td></tr>
<tr><td colspan="2">Discussion:
Retrofitting T8s into T5s is an easy and unobtrusive process. When retrofitting a T5 into a T8, the light fixture can be kept. A new electronic ballast, which fits into the T8 light fixture, is installed and then the T5 fluorescent tube can be placed into the light fixture (EMSD, 2016b)</td></tr>
<tr><td>Data:
(Compared to T8s)
Capital Cost:
15% more expensive (EMSD, 2016b)
Energy savings:
30 to 40% (EMSD, 2016b)</td><td>Advantages:
T5 lamps have a luminous efficiency of 100 lumens/Watt, compared to T8 lamps, which have an efficiency of only 80 lumens/Watt.
They are 30-40% more energy-efficient than T8 fluorescents.
They use less power than T8 fluorescents, which lowers the amount of heat produced and therefore the energy required to cool spaces with these installations.
T5 lamps contain less than 30 mg of mercury compared to 40 mg for T12 lamps, so less mercury is disposed during relamping (EMSD, 2016b)
T5s have a smaller size of only 0.625”, compared to the 1.00” size of T8 lamps.
T5s have a higher optimum operating temperature (95*F) than T8 lamps (77*F), making them more effective in smaller spaces with less ventilation. (Close & Chau, 2010)
Disadvantages:
Material cost of T5 luminaires is about 15% more expensive than T8 luminaires for new projects. However this higher initial cost can be made up for with factors such as its higher efficacy and longer lamp life.(EMSD, 2016b)
According to Interviewee 08, T5 lights have not advanced as much in the past few years compared to LED lighting fixtures (Interviewee 08)</td></tr>
</table>

<table>
<tr><td colspan="2">Room Occupancy Sensors</td></tr>
<tr><td colspan="2">Description:

Proper control systems can significantly reduce the amount of energy consumed by lighting systems. Occupancy sensors detect motion using either infrared or ultrasonic detectors. occupancy sensors determine whether or not a room is occupied and then automatically turn off lights in unoccupied spaces (EMSD, n.d.).</td></tr>
<tr><td colspan="2">Discussion

The amount of energy saved by occupancy sensors depends on the occupancy pattern.

When integrating into existing buildings, managers should consider that installation can disrupt current operations. Managers should also make sure that these devices are compatible with their current lighting fixtures, as occupancy sensors may be incompatible (Interviewee 06). Finally, current lighting practices should be considered. Sensors work best only if occupant behavior change is not possible. If the occupants of an office space already have good lighting practices, i.e. lights are always turned off when exiting rooms, then there is little room for energy efficiency to improve after retrofitting (Interviewee 16).</td></tr>
<tr><td>Data:

(lighting energy use with sensors compared to energy use without sensors)

Capital Cost:

There are many different devices that fall under this category, each with a different cost. Cost also varies based upon whether or not existing systems are compatible (Interviewee 10).

Energy savings:

Case studies in other countries show savings of 15-25% in different spaces and occupancy type (EMSD, n.d.)</td><td>Advantages:

Low investment cost.

Easy to incorporate into existing buildings, as long as lighting fixtures are compatible (Interviewee 10).

Does not require behavioral changes.

Disadvantages:

Older models may be falsely triggered by wind-blown curtains, papers, etc. (EMSD, n.d.)

Savings depend on how often areas are occupied.

Controls may be overridden by users

May be incompatible with existing lighting fixtures (Interviewee 06).

Motion sensors may turn off when there is no motion in a room for an extended period of time, even if occupied because the occupants are not moving (Interviewee 04).

If a room is accessed too frequently, the lighting will never turn off. For example, one room’s device is set to turn off after 30 minutes, but breaks between room occupancy are only 15 minutes (Interviewee 10)

The number of people using a given area may fluctuate in rented properties, so the locations best suited for sensors may change over time (Interviewee 21).</td></tr>
</table>

Task Lighting Design	
Description: In addition to incorporating more energy-efficient technology, it is also important to consider the lighting design to lower energy use in a building. Task lighting is a design practice in which either the number of lighting fixtures installed in a room is minimized, or the existing lights are dimmed (if that feature is available), in order to supply only the required amount of light (EMSD, 2016d). The amount of light required also varies based on the lighting usage of the particular area. Thus, the savings also vary. For example, the amount of light typically produced by lighting fixtures in an office space is around 500 lux. In contrast, the amount of lighting actually needed in an office space was calculated to be just 300 lux for perimeter (window) office spaces and 400 lux for interior office spaces (BEC's Climate Change Business Forum, 2012).	
Discussion: A case study was performed by EMSD, analyzing the benefits of applying task lighting to an office space (Appendix F.17, F.18). They ran two simulations, each with about 495 square meters of office space, and assumed that T5 lighting was used both before and after the retrofit. Both simulations assumed initial ambient lighting levels to be at 500 lux, and reduced the ambient light level to 322 lux for the task lighting designs, by reducing the number of light fixtures. One simulation was for a typical office plan with 55 work stations, each about 4.4 square meters in area, and the other was for a more spacious plan, with 30 work stations, each about 6 square meters in area. The typical plan retrofit provided an estimated energy savings of 22%, while the spacious plan retrofit provided savings of 31%. These results show that the amount of savings accomplished by task lighting varies based on the amount of workstation space in an office (EMSD, 2016d).	
Data: (for office spaces such as the ones analyzed in the EMSD case study (Appendix F.17, F.18)) **Capital cost:** Not using light has no cost. However, if lighting fixtures have to be reconfigured, there may be an initial cost (Interviewee 06). Cost varies based on the current layout and configuration, so cost data is relative to each building. **Energy savings:** 22% to 31% (EMSD, 2016d).	**Advantages:** Task lighting can reduce the amount of energy consumed by lighting significantly, and as long as lighting fixtures do not need to be reconfigured, it can do so while incurring very little cost (Interviewee 06). **Disadvantages:** This type of lighting might result in a specialized general lighting layout. If the floor layout were to change, then the lighting layout would have to be reconfigured. (Interviewee 06)

D.2 Air Conditioning

Oil-free Chillers	
Description: Oil-free chillers are air conditioning systems that use magnets to levitate the parts normally requiring lubricant. The low friction between the parts lowers the energy use compared to an air conditioning system that uses lubricating oil (BEC's Climate Change Business Forum, 2012).	
Discussion: Air conditioning systems typically last for 10 to 15 years with proper maintenance (Interviewee 02). It is more environmentally friendly to retrofit after the air conditioner unit has reached the end of its lifespan. Now that oil-free chillers have been on the market for several years, it has been discovered that these air conditioners work most efficiently at 85% of their maximum load. It is recommended that when installing an oil-free chiller, a larger unit is used to allow it to run at this maximum efficiency threshold for the majority of the time (Jackson Ball, 2017).	
Data: (compared to an equivalent capacity rotary-screw chiller) (SA Parker & J Blanchard, 2012) **Capital Cost:** 30 to 35% more **Energy savings:** 30% savings **Cost savings:** $70,593 HKD/year **Payback period:** 12.8 years	**Advantages:** Significantly less maintenance from parts wearing out and the oil having to be replaced (Jackson Ball, 2017) Oil-free chiller availability and prices have gone down due to an increase in world wide usage as well as Hong Kong suppliers (BEC's Climate Change Business Forum, 2012) They are quiet compared to standard air conditioners (Jackson Ball, 2017) **Disadvantages:** Have to invest in a larger oil-free chiller than required by the building specifications for maximum energy efficiency (Jackson Ball, 2017)

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Variable Speed Drive (VSD) Air Conditioning	
Description: Variable speed drive (VSD) air conditioning involves running motors at lower speeds when the load is lower (BEC's Climate Change Business Forum, 2012). Traditional air conditioning units run at maximum speed until the thermostat sensor shuts off the machine, and then turn it back on when the room heats up again. This process both wastes energy and creates a fluctuating room temperature. VSD air conditioners are able to change the speed of the air conditioner itself to maintain the temperature of the room (EMSD, 2016e).	
Discussion: Air conditioning systems typically last for 10 to 15 years with proper maintenance (Interviewee 02). As such, building managers will likely not want to replace the system each time new technology comes out, instead it is more reasonable to wait for the air conditioner to reach the end of its lifespan. The size of the building and the variation in the air conditioning load are important factors when determining whether a VSD air conditioner will achieve significant savings. If the load on the air conditioning is constant, or the building is larger and requires the air conditioner to run at maximum for long periods of time, a VSD unit will have a longer payback period (Interviewee 3).	
Data: (compared to a non-VSD air conditioner) **Energy savings:** 30% energy savings during the summer season (EMSD, 2016j) **Payback period:** 3 years (Interviewee 10)	**Advantages:** Lower energy loss from not constantly turning machine on/off (EMSD, 2016e) No uncomfortable temperature fluctuation (EMSD, 2016e) **Disadvantages:** Outdoor heat exchange part is typically larger than a traditional unit (EMSD, 2016e) Smaller difference in efficiency for energy saving when running at full load when compared to traditional unit (Interviewee 3)

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Variable Flow Control for Condensing Water Pipes	
Description: Water-cooled central air conditioners utilize water as a medium for heat exchange because water transfers heat more efficiently. In order to ensure that the air conditioning can provide for the full load of the building, the machine is kept at a constant flow even at part load conditions. Variable Speed Drive (VSD) devices are attached to the pipes in the chiller system. They are connected to a temperature sensor and a controller to form the Variable Flow Control. The temperature of the water flowing through the pipes is detected by the sensor and sent to the controller. The controller interprets the temperature data and then communicates to the VSDs to raise or lower the flow rate of the water thus conserve energy at part load conditions (EMSD, 2016f).	
Discussion: Assuming the building is already using water-cooled central air conditioning, retrofitting the unit to have variable flow control is an easy retrofit (EMSD, 2016f). VSD devices have to be installed on the pipes leading out from the water-cooled air conditioner to the building. If the system already has VSD devices installed on the pipes, all that needs to be done is to add a controller to the sensors so that they are effectively used.	
Data: (compared to constant flow water-cooled air conditioning) **Energy savings:** 21.4% to 54.5% or on average 33% (EMSD, 2016f)	**Advantages:** Significant savings during winter or other part load conditions (EMSD, 2016f) Large chiller plants or long operating hours increase the savings that can be gained (EMSD, 2016f) **Disadvantages:** Smaller air conditioning systems will have fewer chances to operate under part load conditions equating to lower savings (EMSD, 2016f)

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Heat Pumps

Description:

Heat pumps transfer thermal energy using water as the medium (Close & Chau, 2010). This technology is used in conjunction with the other technologies in the building to increase the overall energy efficiency of the whole system. For example, Hong Kong buildings typically use the air conditioning unit as a heat sink by drawing out hot air from the building into the unit, absorbing the heat from the air and expelling this unwanted heat out the back of the unit to be utilized elsewhere. Heat pumps utilize this exhaust hot air to heat water, and then transport it to be used for hot showers or boiling water for tea.

Discussion:

Heat pumps were installed in a hotel in Hong Kong, case F.25. The 4 star hotel includes 170 rooms with a pool, hot tub and showers heated by a diesel boiler. The heat pumps were integrated into the hotel's hot water and air conditioning system and the entire system was regulated by a control module. The heat from the air conditioners in the hotel was redirected through the heat pumps to aid in warming the water for showers, the pool and the hot tub. The reduction of energy cost for hot water in the hotel was $90,000 HKD or 57% of the original costs.

Data:

Energy savings:

Savings vary based on the building's heating and cooling, for case study F.25 57% was obtained.

Payback period:

Depends on the site, usually around 2 years (Interviewee 08)

Advantages:

Additions to the building for heating and cooling can benefit from the heat pump system

Disadvantages:

Building energy savings vary greatly

For retrofits, space can be an issue

Variable Speed Drive (VSD) Fans & Motors	
Description: The operating speed of VSD fans and motors is adjustable (Close & Chau, 2010). Running a fan at a lower speed saves energy due to reduced losses due to air resistance. Motors running at full speed also experience more wear at the higher speed. (ebn-papst, 2017).	
Discussion: Retrofitting or replacing fans for the air circulation can be intrusive to the occupants of the building (Interviewee 03). To ease the disruption to tenants, building managers should plan retrofits at the time after the lease ended and before the new tenant moves in. For tenants, the best time is when they first move into the building to have the maximum time for payback.	
Data: **Payback period:** 10 months if operating at 75% power (Mark Silnes, 2017).	**Advantages:** When a fan speed is reduced to half speed, it uses 1/8 of the power used when operating at maximum speed. (ebn-papst, 2017) Lower noise level at low load times Increases lifespan of the motor and decreases maintenance **Disadvantages:** Intrusive renovation is required (Interviewee 03) Investment cost increases depending on the number of devices needed in a building, meaning larger buildings will have a large upfront cost.

<table>
<tr><th colspan="2">Electronically Commutated (EC) Plug Fan</th></tr>
<tr><td colspan="2">Description:
EC plug fan or Electronically Commutated plug fan, does not use a brush to control the electric motor (ebn-papst, 2017). Instead, electronic circuitry controls the rotation of the motor. The motor plugs converts alternating current (AC) to direct current (DC). By using DC instead of AC, the fan does not need to create the additional electromagnetic fields that a normal fan does and instead uses a permanent magnet for the second field saving around 30% of the energy used by a typical AC fan (ebn-papst, 2017).</td></tr>
<tr><td colspan="2">Discussion:
EC plug fans require a moderate retrofit that will disrupt the occupants while the new fans are being installed in the building’s air circulation system. The solution to lowering the obstruction to the tenants would be to retrofit during the end of the lease period before the next tenant moves in.</td></tr>
<tr><td>Data:
(compared to belt driven fan)
Capital Cost: 20 - 30 % increase in price (compared to belt driven fan) (Interviewee 03)
Energy savings:
40% decrease in energy use (compared to belt driven fan) (Interviewee 03)
30% decrease in energy usage (compared to AC fan) (ebn-papst, 2017)</td><td>Advantages:
30% energy efficiency compared to traditional AC fans (ebn-papst, 2017)
Have control over the speed of the motor to save energy (ebn-papst, 2017)
Multiple smaller fans are used together in one device allowing for higher efficiency when running at lower speeds (Interviewee 03)
Disadvantages:
Payback is slower when compared to VSD units. EC fans cost 50% more than a typical VSD unit (Mark Silnes, 2017).</td></tr>
</table>

D.3 Lifts and Escalators

<table>
<tr><th colspan="2">Linear Synchronous Motor (LSM) Lifts</th></tr>
<tr><td colspan="2">Description:
Linear synchronous motor (LSM) lift systems use magnetic field induction to drive the car up rather than traditional motors, eliminating the need for conventional pulley and counterweight systems. LSM systems are safer, faster, and more energy-efficient than conventional systems (Nationwide Lifts, n.d.).</td></tr>
<tr><td colspan="2">Discussion:
This device is more cost-effective in buildings with high elevator speeds. LSM propulsion systems are less costly when cabs operate at higher speeds because the stator duty cycle is low. Therefore, LSMs are favored for use in tall buildings, where the elevator speeds are the greatest, with high amounts of elevator use. (Close & Chau, 2016).</td></tr>
<tr><td>Data:
(Compared to conventional elevator motors)
Energy savings:
For high-rise buildings with elevator speeds of over 10 m/s, the LSM motor efficiency is over 85% (Close & Chau, 2010).</td><td>Advantages:
Since it does not use cables, LSM elevator systems can be operated in a hoist way of any height (Nationwide Lifts, n.d.).
LSM elevators were designed to move cabs very fast, at .75 meters per second, accelerating to full speed in just two seconds.
Without the use of counterweights and pulley systems, the system takes up less space (Close & Chau, 2010).
Disadvantages:
Can be expensive (Close & Chau, 2010).
Lower savings in buildings with less elevator use.</td></tr>
</table>

<table>
<tr><th colspan="2">Lift Destination Control Devices</th></tr>
<tr><td colspan="2">Description:

In elevators banks with more than one shaft, control systems are installed along with a destination control device in which the passengers select their destination before entering the elevator car. The elevator control systems are then able to calculate the most efficient servicing schedule based on the destination entries. This allows the elevator systems to optimize the flow of passengers, minimize the number of stops needed, and increase the operational efficiency of an elevator system (Toshiba, n.d.).</td></tr>
<tr><td colspan="2">Discussion:

The benefits of this technology are dependent on a building’s service patterns, and because these patterns are all specific to different building types and areas, overall data on the benefits of this technology are difficult to provide (Interviewee 08). Before retrofitting, a building manager should analyze their building’s service patterns, and decide if the building can benefit from this technology.</td></tr>
<tr><td>Data:

For elevator destination control systems, the energy savings depend heavily on the usage. There are many different systems incorporating this technology, and some are more advanced than others. The capital cost varies based on the technology provider, and how advanced the new system is.</td><td>Advantages:

Can be incorporated into existing building systems.

By optimizing passenger flow, the wait time for elevators is reduced by an average of 30% (Shindler, n.d.)

Rides will be more comfortable because passengers will not need to operate the destination entry system inside a packed elevator.

More efficient servicing schedules minimize the number of stops and shorten the distance traveled by elevators, making elevators more energy-efficient (Toshiba, n.d.)

Can reduce crowding in elevator loading areas.

Can lower the travel time within elevators by reducing the number of stops within trips.

Can allow buildings to designate certain elevator shafts for specialized uses such as deliveries and other building needs (Otis, 2009).

Disadvantages:

These systems are only able to improve systems in buildings where more than one elevator shaft is operating at a time (Toshiba, n.d.).</td></tr>
</table>

Regenerative Braking	
Description: In conventional lifts, the power generated by traction is dissipated as heat in the building (EMSD, 2016h), whereas lifts with a regenerative function are able to use their motors as a generator when the carriage is traveling down, and feed the current back into the facility’s electrical grid to use elsewhere. During times when a cab is traveling up with a light load, or down with a heavy load, the system can actually generate more power than it uses. Over time, the power generated can add up to noticeable savings. (ASME, 2016).	
Discussion: The amount of energy savings provided by regenerative power varies, based on lift traffic patterns. Specifically, regenerative braking is able to save more energy on lifts that reach higher speeds because more energy is generated during braking (EMSD, 2016h). These patterns are different based on the building’s type and location, and should be kept in mind when considering this retrofit. Some examples are noted below for reference.	
Data: (per device, compared to conventional lifts) **Energy savings:** (% savings and average speed) 17% (1.75m/s) to 27% (5m/s) savings in the study of a central government office. 20 to 30% savings found when incorporated into a housing estate. (EMSD, 2016h)	**Advantages:** Regenerative braking reduces the net power consumption of both the lift and the air conditioning by reducing the amount of heat generated by braking (ASME, 2016) **Disadvantages:** In existing buildings, this may disrupt operation during installation of the parts or it may not be compatible with the other equipment (Interviewee 06).

Service On Demand (SOD) Escalator	
Description: SOD escalators, sometimes referred to as variable speed drive (VSD) escalators, use occupancy sensors to detect the presence of passengers. When no passengers are detected, they will then either run at low speeds (using VSDs) or stop completely to conserve energy (EMSD, 2016i).	
Discussion: The amount of energy saved by these devices depends on the daily service/traffic patterns of the escalator being retrofitted. If an escalator spends less time servicing passengers throughout an average day, then retrofitting will likely save more energy, because the escalator will be able to spend less time operating at normal speeds. It is therefore up to the building manager to evaluate the peak operation times when considering this retrofit (EMSD, 2016i). For example, EMSD performed a simulation to show the overall savings of these devices in a typical ground floor space of an office building in which the non-peak periods were a major component when calculating the savings (Appendix F.21). SOD savings are easier to calculate in buildings such as office spaces, cinemas, theatres, public facilities, and educational institutes, due to their regular traffic patterns. In locations such as shopping malls however, the arrangement of circulation routes and the nature of retail will cause the service patterns of escalators in different areas of the mall to fluctuate over time, which makes it more difficult to calculate the savings (EMSD, 2016i).	
Data: (compared to conventional escalators) **Capital Cost:** Capital cost of this technology varies based on the devices and technology supplier chosen by building managers. **Energy savings:** Auto on-off SOD control: 52% Auto two-speed SOD control: 14% (in a government office building) (EMSD, 2016i) **Payback period:** Varies from one to three years depending on how infrequently the escalator services passengers (Interviewee 08).	**Advantages:** Energy savings of from 52% (Auto on-off SOD) to 14% Auto two-speed SOD) in a government office building (EMSD, 2016i) **Disadvantages:** Savings are dependent on building traffic patterns, and can vary over time. While auto on-off SOD controls can save more energy than two-speed controls, some passengers may mistake the auto on-off escalators as being out of order, while the auto two-speed SOD controls may be more easily adopted by the general public (EMSD, 2016i).

Appendix E List of Energy-Efficient Technologies

This appendix reviews all of the technologies researched in this project. This is sorted into three groups: those included in the final list of technologies, those that were researched and not included, and those that were not researched but are potentially viable. When researching technologies and deciding which would be put into the final recommended list, the team developed three criteria to select those that would be most suitable for use in Hong Kong. The first criterion was that the barriers to implementing a technology could not outweigh its benefits. This primarily meant that the technology was cost-effective with a reasonable payback (generally under 5 years to stay within a company's lease period) and was relatively easy to install during a routine retrofit. The second criterion was that the technology must be suitable for implementation in existing buildings in Hong Kong. The technology had to take into account the terrain and densely populated layout of Hong Kong as well as the humid and warm year round climate. The technology had to either be compatible with current building systems or have the ability to be included in a retrofit. The third criterion was that the technology had to be relatively new, or at least not widespread throughout the city. This was to avoid sharing common knowledge information, focus on educating building managers and owners about new technologies, and provide a new perspective on increasing energy efficiency in Hong Kong.

E.1 Included in the Final List of Technologies

LED Lights

Light Emitting Diode, is a semiconductor chip, which emits electromagnetic waves or light when a voltage is supplied to it (EMSD, 2016a). LEDs are more energy efficient and have a longer lifespan than fluorescent bulbs. Interviewee 08 referred to them as the first technology they recommend due to its lack of barriers and easy installation. LEDs are included because the city still has not begun to use them as widespread as possible (Interviewee 19).

T5 Fluorescent Lamps

T5 lamps are 30% to 40% more energy efficient than T8 fluorescent lamps. T5s operate with a higher frequency of the current in the light, but maintaining the same duty cycle as T8s, to allow the smaller T5 lamps to output a comparable amount of light at (EMSD, 2016b). Some interviewees stated that T5s are no longer relevant while some mentioned that their ease in

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installing them into existing buildings keeps them as a retrofitting option. T5s were included in the list based on the ease of retrofitting from T8s to T5s.

Room Occupancy Sensors

Proper control systems can significantly reduce the amount of energy consumed by lighting systems. Occupancy sensors detect motion using either infrared or ultrasonic detectors. Infrared sensors detect motion when heat sources move and require a direct line of sight, whereas ultrasonic sensors emit high-frequency waves (from 25-40 kHz) and detect the changes in frequency that occur when objects move in a room, and do not require a line of sight. Occupancy sensors are able to determine whether or not a room is occupied and then automatically turn off lights in unoccupied spaces (EMSD, n.d.).

Task Lighting Design

Task lighting is a design practice in which either the number of lighting fixtures installed in a room is minimized, or the existing lights are dimmed (if that feature is available), in order to supply only the required amount of light (EMSD, 2016d). The amount of light required also varies based on the lighting usage of the particular area where task lighting is being applied. Thus, the amount of savings also varies. For example, the amount of light typically produced by lighting fixtures in an office space is around 500 lux. In contrast, the amount of lighting actually needed in an office space is just 300 lux for perimeter (window) office spaces and 400 lux for interior office spaces (BEC's Climate Change Business Forum, 2012).

Oil-Free Chillers

Oil-free chillers are air conditioning systems that use magnets to levitate the parts normally requiring lubricant. The low friction between the parts lowers the energy use compared to an air conditioning system that uses lubricating oil (BEC's Climate Change Business Forum, 2012).

Variable Speed Drive (VSD) Air Conditioning

Variable speed drive (VSD) air conditioning involves running motors at lower speeds when the load is lower (BEC's Climate Change Business Forum, 2012). Traditional air conditioning units run at maximum speed until the thermostat sensor shuts off the unit, and then turn it back on when the room heats up again. This process both wastes energy and creates a fluctuating room temperature. VSD air conditions are able to change the speed of the air conditioner itself to maintain the temperature of the room (EMSD, 2016e).

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Variable Flow Control for Condensing Water Pipes

Water-cooled central air conditioners utilize water as a medium for heat exchange because water transfers heat more efficiently. In order to ensure that the air conditioning can provide for the full load of the building, the machine is kept at a constant flow even at part load conditions. Variable Speed Drive (VSD) devices are attached to the pipes in the chiller system. They are connected to a temperature sensor and a controller to form the Variable Flow Control. The temperature of the water flowing through the pipes is detected by the sensor and sent to the controller. The controller interprets the temperature data and then communicates to the VSDs to raise or lower the flow rate of the water thus conserve energy at part load conditions (EMSD, 2016f).

Heat Pumps

Heat pumps transfer thermal energy using water as the medium (Close & Chau, 2010). This technology is used in conjunction with the other technologies in the building to increase the overall energy efficiency of the whole system. For example, Hong Kong buildings typically use the air conditioning unit as a heat sink by drawing out hot air from the building into the unit, absorbing the heat from the air and expelling this unwanted heat out the back of the unit to be utilized elsewhere. Heat pumps utilize this exhaust hot air to heat water, and then transport it to be used for hot showers or boiling water for tea.

Variable Speed Drive (VSD) Fans & Motors

The operating speed of VSD fans and motors is adjustable (Close & Chau, 2010). Running a fan at a lower speed saves energy due to reduced losses due to air resistance. Motors running at full speed also experience more wear at the higher speed. (ebn-papst, 2017).

Electronically Commutated (EC) Plug Fans

EC plug fan or Electronically Commutated plug fan, does not use a brush to control the electric motor (EBN-PAPST, 2017). Instead, electronic circuitry controls the rotation of the motor. The motor plugs into alternating current (AC) and converts it to direct current (DC). By using DC instead of AC, the fan does not need to create the additional electromagnetic fields that a normal fan does and instead uses a permanent magnet for the second field saving around 30% of the energy used by a typical AC fan (EBN-PAPST, 2017).

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Linear Synchronous Motors (LSM)

Linear synchronous motor (LSM) lift systems use magnetic field induction to drive the car up rather than traditional motors, eliminating the need for conventional pulley and counterweight systems. These LSM systems are able to operate safer, faster, and with greater energy efficiency than conventional systems (Nationwide Lifts, n.d.).

Regenerative Braking

In conventional lifts, the power generated by traction is dissipated as heat in the building (EMSD, 2016h), whereas lifts with a regenerative function are able to use their motors as a generator when the carriage is traveling down, and feed the current back into the facility's electrical grid to use elsewhere. During times when a cab is traveling up with a light load, or down with a heavy load, the system can actually generate more power than it uses. Over time, the power generated can add up to noticeable savings. (ASME, 2016).

Service On Demand (SOD) Escalators

SOD escalators, sometimes referred to as variable speed drive (VSD) escalators, use occupancy sensors to detect the presence of passengers. When no passengers are detected, they will then either run at low speeds (using VSDs) or stop completely to conserve energy (EMSD, 2016i).

Lift Destination Control Devices

In elevators with more than one shaft, control systems are installed along with a destination control device in which the passengers enter in their destination before entering the elevator car. The elevator control systems are then able to calculate the most efficient servicing schedule based on the destination entries. This allows the elevator systems to optimize the flow of passengers, minimize the number of stops needed, and increase the operational efficiency of an elevator (Toshiba, n.d.).

E.2 Not Included in the Final List of Technologies

Light Emitting Capacitor (LEC) Exit Signs

LECs require less input power than LEDs to operate. They are more commonly installed in new buildings because both LED and LEC last a long time, around 50,000 hours each, meaning that it will be several years before the LEDs need to be replaced for a retrofit. They also have important safety benefits in being more easily seen through smoke (EMSD, 2016c).

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Conventional T5 signs have an input power of 17 watts while LED and LEC signs have input powers of 3.35 watts and 3.07 watts respectively and thus, have a high potential for saving energy (Hong Kong Electrical and Mechanical Services Department [EMSD], 2016c)

However, since the savings were small compared to LED exit signs, and because lifespans of exit signs are quite long and exit signs should only be replaced at the end of their lifespan (EMSD, 2016c) LEC exit signs were considered by the team to be too small of an improvement to merit any further research or to include in interviews, and were removed from the list.

Daylight Sensors

Daylight sensors measure how much daylight comes into a building, and lower the amount of light needed accordingly. Daylight sensors were not included in the list because we learned during our interview with a tech consultant from company I that most of the clients would manually turn up the lights, and ignore the sensors even though they were installed (Interviewee 08), meaning it was less suitable for use in Hong Kong.

Smart Glass and Facade Treatment

By implementing smart glass and facade treatment on buildings, less solar heat enters into rooms of the building. Less air conditioning is needed to cool the buildings and thus, energy is saved. Certain facade treatments, such as designing the shape of the building to prevent sunlight from heating up the room are not available or more expensive to retrofits. Long return on investments are a large barrier for investment into smart glass and facade treatment. There is also the problem of being restricted by building codes and access for tenants to make any changes on the outside of the building. The team decided that this technology is outside the scope of the project, because the project focuses on energy consumption technologies. While smart glass can lower the amount of energy used in a building, it is not directly using energy and thus the team did not include it into the list.

Ground Source Heat Pumps

This type of heat pump uses waste heat from the ground as the medium for heat exchange to heat water. This was not included in the list because they are impractical in Hong Kong as they require a soft soil, and most of Hong Kong is built into rock (Interviewee 07).

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Chilled beams

Cold water instead of air is pumped to each system, meaning the system can be smaller. There are two designs, one where the water pipes cool the metal plates on the ceiling, which then cool the room through convection or, more efficiently, not have the metal plate and have the water pipes be along the ceiling to directly cool the room. (Butler Memorial Hospital, 2010). However, it was discovered during our interview with Interviewee 15 that chilled beams do not work well in places with high humidity. Water condenses on the metal and drips all over the room. Chilled beams were determined by the team to be unsuitable in Hong Kong's climate, and were taken out of the team's final list.

Four Pipe HVAC System

This system uses 4 pipes: a return and supply pipe for both heating and cooling, which increases efficiency by separating the two systems. This technology was not included due to the problem of retrofitting not being an option if the building did not have room for an additional 2 pipes, as well the increased maintenance required (Neptronic, 2016). Also, due to Hong Kong's hot climate, buildings do not have central heating systems, leaving very little reason to have two additional pipes (Interviewee 6).

Carbon Fiber Based Elevator Cables.

Carbon fiber is used as a replacement for steel elevator cables, as it is lighter which means less energy is wasted from hauling a heavy cable and they last longer (IJEMR, 2016). This technology was not included in the final list because carbon fiber cables cost significantly more than steel cables. Although the price is coming down, it is not yet feasible to begin incorporating them into buildings with fewer stories. In taller buildings, it is more cost-effective, but is still too costly. The first building in China to incorporate carbon fiber cables was the China Zun building in Beijing (KONE, 2016).

Solar Panels.

Use of solar panels for heating water or powering electrical devices has become more popular in the US (BEC Energy Advisory Group Workshop, 2017), but they are not well accepted in Hong Kong. Many interviewees mentioned that there is not enough space in the city to place them, the fog reduces the efficiency, and that tall buildings built nearby would cast shade on the panels. Due to regulations to preserve the visibility of Victoria Peak's view line from Kowloon, some companies wishing to use solar on the roof of their buildings on Hong Kong Island can assess the neighboring buildings to know if future buildings will block their

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building. Solar panels, when carefully planned and implemented into a building, have the ability to pay back on the initial investment. This technology was not included due to the barriers of fog from Hong Kong lowers the rate at which solar panels can generate electricity, ROI is larger, and in some cases, the city landscape will prevent the ability to for the technology to operate effectively at all if they are overshadowed by another building.

E.3 Further Technologies to Consider

The scope of this project was limited to electrical installations in existing commercial buildings and the timeframe was limited to 7 weeks in Hong Kong. Due to these limitations, the team was only able to consider a small sample of technologies. There are many more that may be viable for use in Hong Kong that were not considered. Some further technologies are:

Compiled from: (Hong Kong Construction Industry Council, 2012), (EMSD, 2016l), and Interviewees 06, 07, 08, 10, 16, 19, 21

3M Solar Film

Adsorption Chiller

Anti-Ultraviolet Film

Automatic Tube Cleaning System For Chiller

Bio-diesel Generator

Bio-Diesel Tri-Generation

Building Analytics

Ceiling Type Eco-Fan

Chilled/Hot Water Control Valves

Chiller Optimization Controls

Cloud Energy Management Platform

CO_2 Controls and Monitoring

Cooling Tower

DC Specialized Motor

Demand Control Ventilation

Desiccant Dehumidification

Desiccant Wheel

Dimming Control for Lighting

Electric Current Optimization System

Electrodeless Discharge Lamp

Electrostatically Charged Synthetic Media HVAC Filter

Energy Management Opportunities (EMO)

Expertized Room Control (utilizing mini-BMS)

Façade Treatment- Sun Zero

Fiber Optic Lighting

Heat Pipe

Heat Recovery Chiller

High-Volume-Low-Speed Ceiling (HVLS) Fan

Induction Lamp

Information of Things (IOT) Wireless Metering Strategy

Insulation on Pipes and Ducts

Light Pipe

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Appendix F: Case Study Compilation

Case studies were compiled from a variety of sources including interviewees and EMSD. All of the data provided in these studies was gathered by outside sources and compiled by the students for this report. The data provided for each study varied by source.

F.1 List of Case Studies

Appendix	Title	Category
F.2	Addition of Daylight Sensor with Dimming Effect at the Corridor of an Office Floor	Daylight Sensor
F.3	Addition of Occupation Sensors at the Toilets of an Office Floor	Occupancy Sensors
F.4	Upgrade to Oil-free/Magnetic Bearing Chiller in an Office Building	Oil-free/Magnetic Bearing Chiller
F.5	Replacement of Light Tubes with LED Fixtures at the Public Area of an Office Building	LEDs
F.6	Bank Office A Retrofit	Multiple
F.7	Hotel A Energy Management	Multiple
F.8	Bank B Main Building Assessment	Multiple
F.9	Hotel B Energy Management	Multiple
F.10	Hotel B Chiller Optimization Program	Multiple
F.11	Chillers, Boilers and Heat Pumps Replacement	Multiple
F.12	Kitchen Exhaust Demand Control Ventilation	Multiple
F.13	Lighting Upgrade	LED
F.14	EC Upgrades, Fan Retrofits by EBM-PAPST	EC Plug Fan
F.15	The Holiday Inn Express SoHo	Multiple
F.16	Zumtobel Lighting Design	Multiple
F.17	Task Lighting - Case Study, Case 1: The Energy Saving Potential of a Typical Open Plan Office	Task Lighting
F.18	Task Lighting - Case Study, Case 2: The Energy Saving Potential of a More Spacious Open Plan Office	Task Lighting
F.19	Variable Flow Control for Condensing Water Pumps, Pilot Project	Variable Flow Control for Condensing Water Pipes
F.20	Study Report on Application of Lift Regenerative Power, Regenerative lifts at the Tamar Central Government Offices	Regenerative Braking Lifts
F.21	Service on Demand (SOD) Escalator, Example of Energy Saving Estimation for Existing Escalator	Service on Demand (SOD) Escalator
F.22	Using a Heat Pump for Hot Water Showers	Heat Pump
F.23	Using a Heat Pump for a Hydrotherapy Pool	Heat Pump
F.24	Using a Heat Pump for an Industrial Laundry Facility	Heat Pump
F.25	Hydra Balance System	Heat Pump

F.2 Addition of Daylight Sensor with Dimming Effect at the Corridor of an Office Floor

Source document: (BEC, 2016c)
Company: BEC
Year completed: 2014
Building Type and Size:
Low rise office, two office floors, one reception floor, and a basement floor
Previous System:
T8 fluorescent lights with an input power 72 Watts. The input power is of the entire panel and includes two T8 fluorescent lights with electronic ballasts.
Description of Retrofits or Retrocommissioning Undertaken:
Daylight sensors were installed throughout the building to detect the level of daylight and lower the lights in the building and save energy.
Numbers and Data

Cost of investment in the project: $3466 HKD
Energy usage before retrofit: 688(KWh)
Energy usage after retrofit: 480(KWh)
Energy saved: 208.48 KWh per year and 30.3% saved
Cost savings: $256.43 HKD per year
Payback period: 13 years.
Note: The payback period is 13 years due to the relatively small scale of work which increases the initial cost.

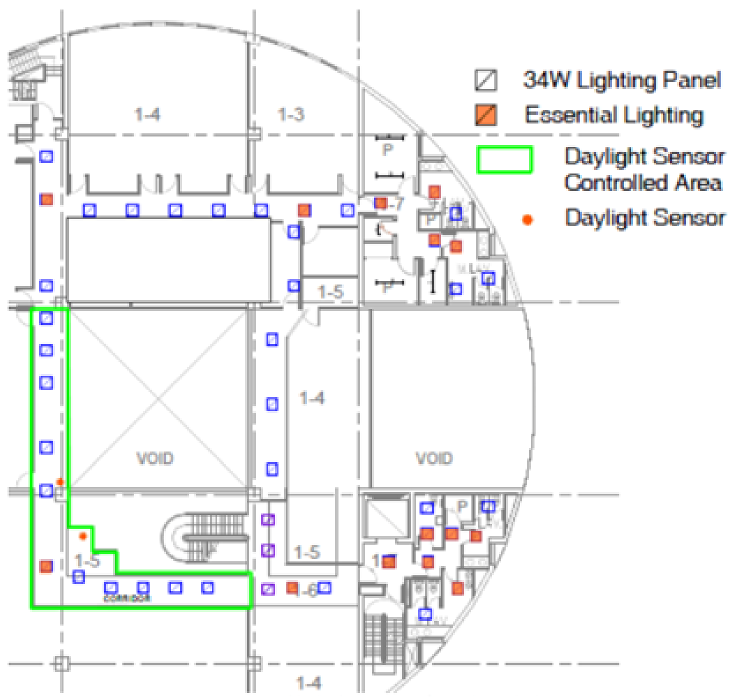


Figure F.1: Layout of light fittings on the first floor with daylight control (BEC, 2016c).

F.3 Addition of Occupation Sensors at the Toilets of an Office Floor

Source document: (BEC, 2016d)
Company: BEC
Year completed: 2014
Building Type and Size:
Low rise office, two office floors, one reception floor, and a basement floor
Previous System:
T8 fluorescent lights with an input power 72 Watts. The input power is of the entire panel which includes two T8 fluorescent lights with electronic ballasts to be installed.
Description of Retrofits or Retrocommissioning Undertaken:
Occupancy Sensors were installed to detect the presence of people entering the room and turn off the lights after 30 minutes of no movement.
Numbers and Data

> **Cost of investment in the project:** 3456 HKD
> **Energy usage before retrofit:** (KWh)
> **Energy usage after retrofit:** (KWh)
> **Energy saved:** 185.88 KWh per year and 29.4 % saved
> **Cost savings:** 228.63 HKD
> **Payback period:** 15.1 years

Note: The payback period of this project is 15 years due to the high initial cost in comparison to the number and use of the lights under control of the sensors.

F.4 Upgrade to Oil-free/Magnetic Bearing Chiller in an Office Building

Source document: (BEC, 2016b)
Company: BEC
Year completed: 2014
Building Type and Size:
Low rise office, two office floors, one reception floor, and a basement floor
Previous System:
Two 150 Ton of Refrigeration (TR) or 1800000 BTU/hour air-cooled chillers had previously been installed.
Description of Retrofits or Retrocommissioning Undertaken:
One air-cooled chiller was replaced with an oil free chiller with the same capacity.
Numbers and Data

Cost of investment in the project: 1,447,859.0 HKD
Average cost of investment in regular chiller: 1,000,000.0 HKD
Energy usage before retrofit: 1,606.2(KWh)
Energy usage after retrofit: 1125.77 (KWh)
Energy saved: 480.43 KWh per year and 29.9% saved for cooling
Cost savings: 59,905.06 HKD per year
Payback period: 24.2 years
Payback period for additional cost: 7.48 years
Note: The payback period of this project is 24.2 years. One reason is that the chiller is not fully utilized. The building owner will replace the remaining old air-cooled chiller in due course, and the capacity of the new oil-free chiller to be purchased is only around 110 TR which costs around1.1 million HKD. If this value is adopted as the initial cost, the corresponding payback period (assuming the same energy saving) will be reduced to around 18 years.

F.5 Replacement of Light Tubes with LED Fixtures at the Public Area of an Office Building

Source document: (BEC, 2016a)
Company: BEC
Year completed: 2014
Building Type and Size:
Low rise office, two office floors, one reception floor, and a basement floor
Previous System:
T8 fluorescent lights with an input power 72 Watts. The input power is of the entire panel which includes two T8 fluorescent lights with electronic ballasts to be installed.
Description of Retrofits or Retrocommissioning Undertaken:
Installation of LED luminaires with an input power of 34 Watts. The input power is of the entire panel which includes the LED luminaries.
Numbers and Data

Cost of investment in the project: 43,120HKD
Energy usage before retrofit: 17,260(KWh)
Energy usage after retrofit: 7432(KWh)
Energy saved: 9,828 KWh per year and 57% saved
Cost savings: 12,090HKD per year
Payback period: 3.6 years

F.6 Bank Office A Retrofit

Source document: (Energenz, 2016a)
Building Type and Size: Commercial/office, 48,588 m^2
Year completed: 2015
Previous System:
The total cooling capacity of the air conditioning is 4,573kW (1,300RT).
Description of Retrofits or Retrocommissioning Undertaken:
Energy and Carbon Audit, Site Assessment,
Implementation on multiple office sites,
Installation of Energy metering, air side equipment,
variable speed drive control,
electricity tariff opportunities, lighting opportunities,
data center computer room air conditioning (CRAC) unit optimization.
Numbers and Data

Cost of investment in the project: Not disclosed
Energy Usage before retrofit: 11,091,348 kWh
Energy saved: 1,617,119 kWh per year
11% energy intensity reduction
Cost savings: greater than USD $225,000 per year
Payback period: Not disclosed

F.7 Hotel A Energy Management

Source document: (Energenz, 2016a)
Building Type and Size: Casino and Hospitality; five-star hotel, about 30,000 m^2
Year completed: 2010-present
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Worked on Hotel A to lower its overall energy use.
Performed energy Audit, onsite workshops,
Energy Management Program, Energy Information System,
Gas Boiler Replacement with Heat pumps (USD $650,000 cost savings per year) (Energenz, 2016a),
Chiller plant Optimization program (41% savings) (Energenz, 2016a),
water efficiency assessments, waste assessments.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy Usage before retrofit:** 75,000,000 KWh
- **Energy Usage after retrofit:** Not disclosed
- **Energy saved:** Verified 28% savings to date
- **Cost savings:** Not disclosed
- **Payback period:** Not disclosed

F.8 Bank B Main Building Assessment

Source document: (Energenz, 2016a)
Building Type and Size: Commercial/banking, more than 260,000m^2
Year completed: 2014
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Performed energy audit, site assessment, real-time data logging, and onsite workshops to help the client lower its overall energy usage.
Performed:
ASHRAE Level 2 energy audit, real-time data logging, site assessment.
Recommended:
Fine-tune chiller operations, variable speed drive controls,
lighting operation monitoring and control, electricity tariff opportunities.
Numbers and Data

Cost of investment in the project: Not disclosed
Energy Usage before retrofit: greater than 30,000,000 kWh
Energy Usage after retrofit: Not disclosed
Energy saved: greater than 8,000,000 kWh per year
11% energy intensity reduction
Cost savings: greater than USD $1,800,000 per year
Payback period: Not disclosed

Note: The building achieved LEED certificate.

F. 9 Hotel B Energy Management

Source document: (Energenz, 2016a)
Building Type and Size: Hospitality, five-star hotel, about 500 rooms, more than 5 restaurants.
Year completed: 2015
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Acted as the Energy Manager for Hotel B in Hong Kong. Identified savings opportunities. Were successful despite the fact that 2015 was one of the hottest recorded years in Hong Kong. Chiller optimization (19% of the chiller plant saving, 5% of site energy saving) (Energenz, 2016a).
Numbers and Data

Cost of investment in the project: Not disclosed
Energy Usage before retrofit: 11,091,348 kWh
Energy Usage after retrofit:
Energy saved: Electricity reduction of -0.9%
Normalized reduction of -2.1% against 2014 baseline
Cost savings: HKD $300,000 from lowering electricity yearly
HKD $715,000 total yearly savings when compared to 2014 baseline
Payback period: Not disclosed

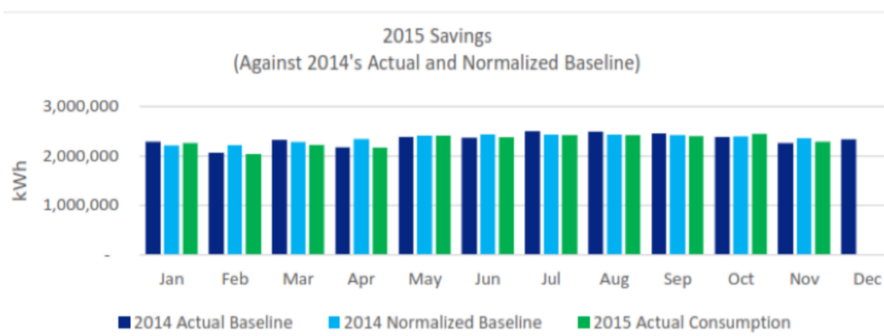


Figure F.2: Savings data by month (Energenz, 2016a)

F.10 Hotel B Chiller Optimization Program

Source document: (Energenz, 2016a)
Building Type and Size: Hospitality, five-star hotel
Year completed: 2013
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Chiller optimization program was a comprehensive study on chiller operation, focusing on all possible options for energy savings in that area. Performed chiller staging modifications, chiller optimization, electrical data logging, capital improvement, detailed reporting, maintenance issue advisory (19% of the chiller plant saving, 5% of site energy saving) (Energenz, 2016a).
Numbers and Data
Cost of investment in the project: Not disclosed
Energy Usage before retrofit: 7,500,000 KWh
Energy Usage after retrofit: Not disclosed

> **Energy saved:**
> Energy reduction to date of 35% on mechanical systems
> Greater than USD $360,000 per year energy savings implemented.
> **Cost savings:**
> Operational cost savings of 18%, with 5% savings requiring some capital expenditure.
> Overall savings of over USD $ 1M per year on their chiller plant.
> **Payback period:** Not disclosed

F.11 Chillers, Boilers and Heat Pumps Replacement

Source document: (Energenz, 2016c)
Building Type and Size: Not disclosed
Year completed: In progress
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Chiller optimization program was a comprehensive study on chiller operation, focusing on all possible options for energy savings in that area. Performed chiller staging modifications, chiller optimization, electrical data logging, capital improvement, detailed reporting, maintenance issue advisory.
Numbers and Data

> **Cost of investment in the project:** Not disclosed
> **Energy Usage before retrofit:** Not disclosed
> **Energy Usage after retrofit:** Not disclosed
> **Energy saved:** Expected savings of 30% compared to the existing chiller systems. Expected 3.4% savings for the total site.
> **Cost savings:** Not disclosed
> **Payback period:** Not disclosed

F.12 Kitchen Exhaust Demand Control Ventilation

Source document: (Energenz, 2016b)
Building Type and Size: Not disclosed
Companies involved:
Restaurant A,
Hotel A – 5- star hotel,
Office Building A,
Convention and Exhibition Centre A,
Hotel B - five-star hotel,
Year completed: July, 2016
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
Kitchen loads vary throughout the day. Therefore, variable speed drives, along with temperature, smoke, and steam sensors and controls, to manage the energy use of exhaust fans within kitchens were implemented. In addition, a controller to modulate based on the cooking load, and data from exhaust stream sensors is also used (can be modulated from 30-100%).
Numbers and Data

System Savings: 5% to 15%
Payback: less than 2.0 years

Table F.1: Example data on paybacks, project cost and savings, and energy savings. (Energenz, 2016b)

Energy Management Opportunity Savings				
Project	Project Cost (HKD)	Cost Saving (HKD/Year)	Payback (Year)	Energy Saving (kWh/Year)
Restaurant A	14 Million	4.5 Million	5.0	4 Million
Hotel A	450,000	450,000	1.0	360,000
Office Building A	50,000	23,000	2.2	26,000
Convention & Exhibition Centre A	230,000	450,000	0.5	320,000
Hotel B	1.7 Million	614,000	1.7	646,000

F.13 Lighting Upgrade

Source document: (Energenz, 2016c)
Year completed: Not disclosed
Building Type and Size:
Hotel C – 5-star hotel, more than 2,000 rooms, more than 50 food outlets
Hotel D – 5-star, more than 400 rooms.
Previous System:
Buildings were using obsolete lighting technology such as incandescent/halogen bulbs.
Description of Retrofits or Retrocommissioning Undertaken:
The previous lighting system was replaced with LEDs.
Numbers and Data
Hotel C is implementing projects that will amount to 23% energy savings, which included significant lighting upgrades.
Hotel D implemented projects of 20% energy savings, which included significant upgrades.

Table F.2: General lighting data comparing LED and Halogen/Incandescent bulbs. (Energenz, 2016c)

Incandescent/ Halogen Wattage	Lumens	LED equivalent Wattage	Savings Percentage
25	250	4-9	76%
40	450	9-13	73%
60	800	13-15	76%
75	1110	18-25	71%
100	1600	23-30	75%
125	2000	22-40	76%
150	2600	40-45	71%

F.14 EC upgrades, Fan retrofits by EBM-PAPST

Source document: (EcoLink, N.D.)
Company: Not disclosed
Year completed: Not disclosed
Building Type and Size:
Typical commercial building, Grade A, unnamed. 34 office floors, one air handling unit (AHU) per floor.
Previous System:
Up to 70% of total energy consumption is contributed to the heating, ventilation, and air conditioning (HVAC) systems (EcoLink).
Fan consumption is 30% of the entire consumption in a commercial building.
Description of Retrofits or Retrocommissioning Undertaken:
Replaced the AC fan on the 32nd floor with an EC plug fan system, once it had come to the end of its life.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** 40,000 KW (for device)
- **Energy usage after retrofit:** 19,000 KW (for device)
- **Energy saved:** 21,000 KW (for device)
  and/or: 52.5 % saved (for device)
- **Cost savings:** HKD $27,000
- **Payback period:** Not disclosed

Note: Approximately 40% of energy can be saved by replacing the existing AC belt driven fan throughout a commercial building to EC plug fans.

F.15 The Holiday Inn Express SoHo

Source document: (Interviewee 04)
Building Type and Size: Holiday Inn Express SoHo Hotel, 264 rooms.
Introduction: Yau Lee Holdings invested and partnered with Holiday Inn Express to build an energy efficiency hotel in SoHo. Their holistic approach included considering the most energy efficiency building orientation, building materials, mechanical and plumbing systems, and controls. This project has received four green awards: HK BEAM-Plus Platinum, US LEED Platinum, Singapore BCA Green Mark Platinum, and China Green Building Council Three-Star.
Year completed: 2010
Description of New Construction Energy Saving Measures Taken:
Solar Hot Water Collector System: This system circulates the water through the heat exchanger and consists of a vacuum tube type solar collector. The system accounts for 1.32% of the building's total energy consumption and saves 70,000 kWh per year when compared to a similar existing hotel.
Low e Glass and Double Glazing
Building Management System
Chiller: The chiller has a 5.48 Coefficient of Performance
Building Management System Control
Heat Pump: The heat pump offers cooling for air conditioning and heating for hot water. It saves heating energy production and reduces the cooling load to the chiller plant. The annual energy savings, when compared to a similar existing hotel, are 667,60 kWh/year (hot water) and 84,025 kW/year (cooling) and overall have a 37.36% savings.
Energy Efficiency Products
Motorized Roller Blind: The blinds will automatically close when the hotel guest rooms are unoccupied and thus reduces the additional solar heat in the rooms.
Chilled Headboard
*Solar Hot water Pane*l: The curtain wall cladding has pipes integrated in to use solar energy to heat water.
iFCU™
Lift Counterweight Optimization: This optimization has 13% savings.
PowerBox Energy Monitoring System
Pattern Recognition Energy Savings Solution (PRESS): This system uses CCTV cameras to identify human silhouettes in order to determine occupancy in common areas such as hallways. This system is an improvement over traditional motion sensors because it can detect humans even if they are not moving.
Energy Optimization: This saves 125,000 kWh/year
Data:

Energy Consumption reduced: 2,070,381 kWh
Additional Cost: 13.26 million HKD
Return on Investment: 25%
Payback period: 3 years 9 months
Energy Bill saved: 3.33 million HKD per year
Energy Usage: 181 kWh/m^2 per year
Energy Saving:
58.5% (Compared to Hong Kong EMSD hotel energy consumption benchmark of 437.5 kWh/m^2

per year).
60.6% (Compared to similar Hong Kong hotel of 460 kWh/m^2 per year)

F.16 Zumtobel Lighting Design

Source document: (Delta Pyramax Company Ltd, 2010)
Company: Delta Pyramax
Year completed: 2010
Building Type and Size:
Delta Pyramax office, 600 m^2
Previous System:
They used a combination of task lighting design, and motion sensors to switch off the lights when not needed. Task lighting needed to provide the company's previously agreed upon desk surface light levels of 350 lux and above. 42 luminaire for an area of 255 square meters. Each luminaire is 51 Watts, so energy is 8.4W/sqr meter or 0.8W/sqr foot. Conventional lighting units will need 64 fixtures, at 108W each, so is 27W/square meter. This is 3 times more than the lighting they implemented. For their office of 600 square meters, the total savings on lighting power is 11kW. Because these lights use less power, they will also generate less heat, which saves air conditioning energy. Data sheet figures are shown on the next page.
Unfortunately, the data did not contain information on their previous system's technology. However, they did provide before and after figures along with their own recorded savings.
Description of Retrofits or Retrocommissioning Undertaken:
A combination of task lighting design, and occupancy/motion sensors.
Installed T5 fluorescent lighting.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** Not disclosed
- **Energy usage after retrofit:** Not disclosed
- **Energy saved:** 11 (KW)
- **Cost savings:** Not disclosed
- **Payback period:** Not disclosed
- **Additional figures:** (see next page)

Every + symbol in Figure F.3 is the location of a Zumtobel Mellow Light.

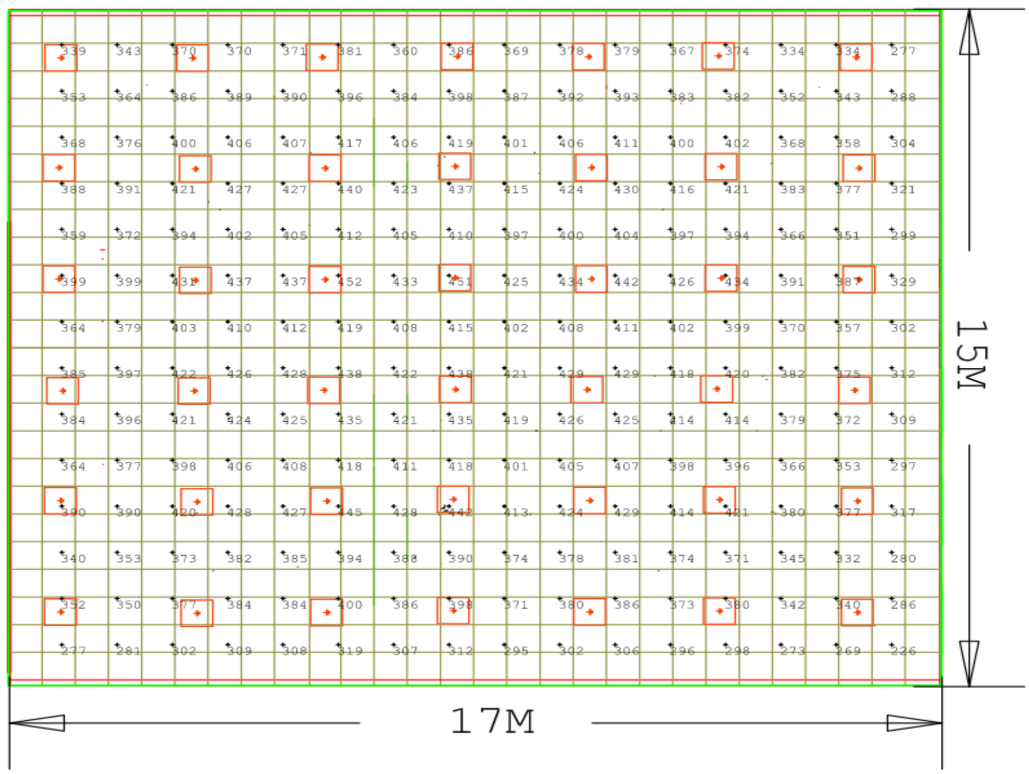


Figure F.3: Diagram of Delta Pyramax Office Space (Delta Pyramax Engineering Ltd, 2010)

Table F.3: Luminaire Schedule (Delta Pyramax Engineering Ltd, 2010)

Luminaire Schedule			
Description	Quantity	Lumens	Arrangement
Zumtobel Mellow Light	42	200	Single

Table F.4: Calculation Summary (Delta Pyramax Engineering Ltd, 2010)

Calculation Summary						
Calculation Type	Units	Average	Maximum	Minimum	Average/ Minimum	Maximum/ Minimum
Illuminance	Lux	383.20	452	226	1.69	2.00

F.17 Task Lighting - Case Study, Case 1: The energy saving potential of a typical open plan office

Source document: (EMSD, 2016d)
Company: EMSD Hong Kong
Year completed: Not disclosed
Building Type and Size:
Office Space:15m X 33m, 495 m2
Previous System:
Ran a simulation on the benefits of implementing task lighting into a theoretical office space, assuming that 15% of total office space was for analytical areas. Estimated that around 55 workstations, each being about 2m X 2.2 m, 4.4 m2. Office in the simulation was assumed to use T5 fluorescent lighting.
Simulated the conventional design approach provided and illumination level of 500 lux, and 550 lux with ambient light included.
Description of Retrofits or Retrocommissioning Undertaken:
Task lighting using T5 fluorescent lighting fixtures.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** 7,488 W
- **Energy usage after retrofit:** 5,805 W
- **Energy saved:** 1,683 W
  22% savings for lighting fixtures
- **Cost savings :** Not disclosed
- **Payback period :** Not disclosed

Additional figures: (see next page)

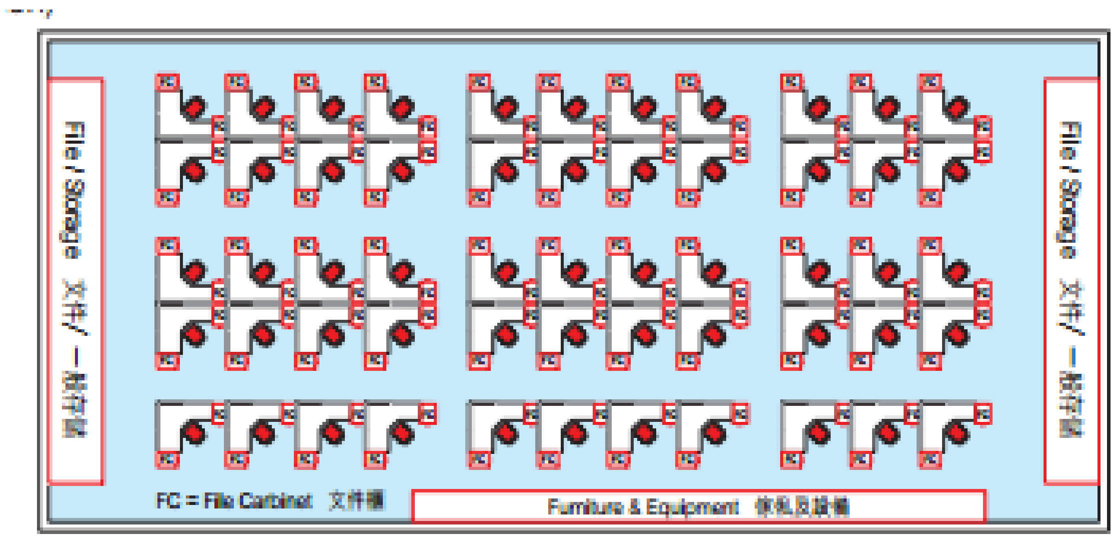
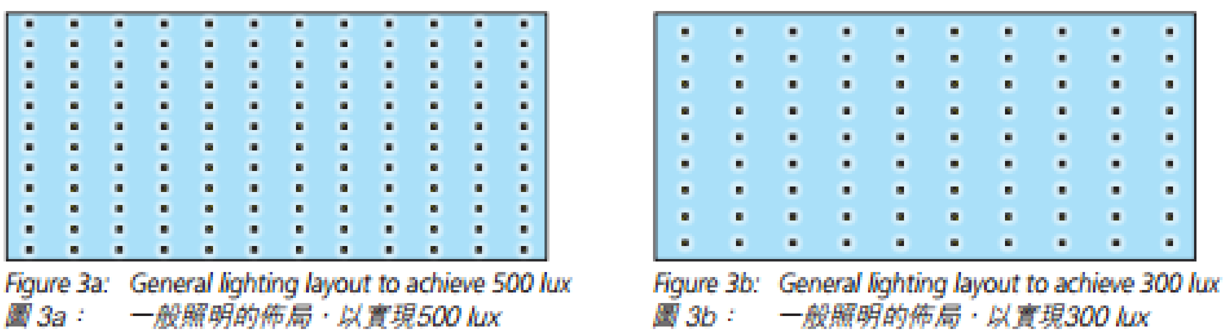


Figure F.4: Diagram of the typical open plan office used for simulation (EMSD,



2016d)

Figure F.5: conventional lighting vs. task lighting example (EMSD, 2016d)

F.18 Task Lighting - Case Study, Case 2: The energy saving potential of a more spacious open plan office

Source document: (EMSD, 2016d)
Company: EMSD Hong Kong
Year completed: Not disclosed
Building Type and Size: Office Space:15m X 33m, 495 m2
Explanation:
Ran a simulation on the benefits of implementing task lighting into a theoretical office space, under the same assumptions as case 1, except that each workstation occupies larger space.
Assumed spacious workstations to be: 2 m X 3 m, 6 m2
Simulated the conventional design approach provided and illumination level of 500 lux, and 550 lux with ambient light included.
Description of Retrofits or Retrocommissioning Undertaken:
Task lighting using T5 fluorescent lighting fixtures.
Simulated the task lighting design approach to be providing only 300 lux, and 322 lux with ambient light included.
Numbers and Data

> **Cost of investment in the project:** Not disclosed
> **Energy usage before retrofit:** 7,488 W
> **Energy usage after retrofit:** 5,130 W
> **Energy saved:** 2,358 W**,** 31% savings for lighting fixtures
> **Cost savings:** Not disclosed
> **Payback period:** Not disclosed

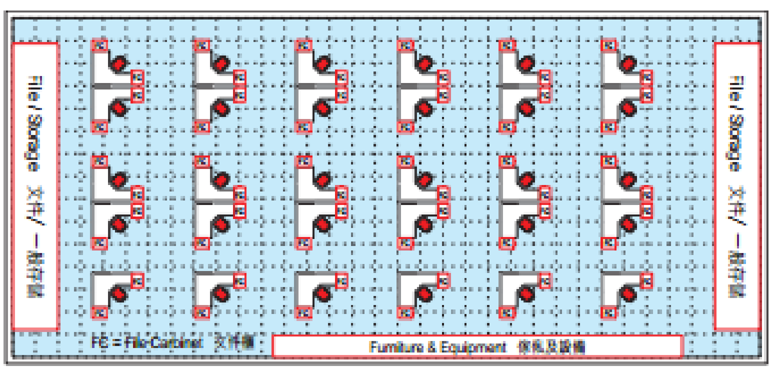


Figure F.6: diagram of more spacious open plan office used for simulation (EMSD, 2016d)

F.19 Variable Flow Control for Condensing Water Pumps, Pilot Project

Source document: (EMSD, 2016f)
Company: EMSD Hong Kong
Year completed: Not disclosed
Building Type and Size: Office
Previous System: Not disclosed
Description of Retrofits or Retrocommissioning Undertaken:
A Variable Condensing Water Flow Control System in one of the government premises.
The energy consumption of the condensing water pumps controlled by this technology were recorded from May 2008 to April 2009 covering a full spectrum of operating conditions from cold winter to hot summer.
Numbers and Data

Number of condensing water pump: 4
Rating of pump motor: 75 kW
Original Control System: Constant Flow
Variable speed drive equipped: Yes
Pump Operating hour: 10 hours per day
Condensing water circuit: Centralized Piped Supply System using seawater
Monthly energy saving: 21.4% to 54.5% (Average: 33%).
Savings are significant during the winter period.

Note: The Variable Condensing Water Flow Control Strategy enables the condensing water pumps to be operated more closely with the cooling demand of the building and reduces energy waste due to excessive condensing water flow.

F.20 Study Report on Application of Lift Regenerative Power, Regenerative lifts at the Tamar Central Government Offices

Source document: (EMSD, 2016h)
Company: Tamar Central Government Offices
Year completed: Not disclosed
Building Type and Size: Office, more than 23 floors
Previous System: Not disclosed
The energy savings were inherently varied based on usage and operating factors such as: design capacity, travelling speed, loading profile and travel distance.
Description of Retrofits or Retrocommissioning Undertaken:
Regenerative braking lifts were incorporated at Tamar Central Government Offices building. Lifts were designed to achieve flexibility services for low (1/F to 14/F) floors, and high zones (1/F, 14/F to 23/F) of east and west wing. Studied the overall use of elevators at different operating capacities and speeds.
Numbers and Data
Results are shown in table F.5 below. Overall, savings ranged from 17% to 27%
Additional table: (see next page)
Note: The energy savings were inherently varied based on usage and operating factors such as: design capacity, travelling speed, loading profile and travel distance.

Table F.5: Case study in depth results for regenerative braking lifts (EMSD, 2016h)

Lift Number (Speed)	Item	Energy from 16 August to 16 December 2013 (kWh)	Percentage of Electricity Saving
East Wing High Zone (6 m/s)	Energy Consumed	45,913	25.7%
	Energy Regenerated	15,847	
East Wing Low Zone (5 m/s)	Energy Consumed	29,311	22.4%
	Energy Regenerated	8,459	
West Wing High Zone (5 m/s)	Energy Consumed	43,518	27.0%
	Energy Regenerated	16,072	
West Wing Low Zone (2.5 m/s)	Energy Consumed	24,640	18.9%
	Energy Regenerated	5,760	
East Wing Passenger (High + Low Zone) (3 m/s)	Energy Consumed	9,405	23.3%
	Energy Regenerated	2,852	
West Wing Passenger (High + Low Zone) (3.5 m/s)	Energy Consumed	16,181	26.4%
	Energy Regenerated	5,796	
East Wing Services (High + Low Zone) (3 m/s)	Energy Consumed	7,361	22.4%
	Energy Regenerated	2,120	
West Wing Services (1^{st} to 3^{rd} floor) (1.75 m/s)	Energy Consumed	2,505	17.1%
	Energy Regenerated	565	

F.21 Service on Demand (SOD) Escalator, Example of Energy Saving Estimation for Existing Escalator

Source document: (EMSD, 2016h)
Company: Not disclosed
Year completed: Not disclosed
Building Type and Size:
simulation scenario: office building,
Previous System:
In the simulation scenario, an existing single speed escalator is installed at the ground floor of an office building, with a passenger transfer time of 27 sec/trip, and is operated from 8:00 to 22:00 daily for 6 days a week. During the simulation, the assumed peak periods throughout the day were:

- Non peak period 1: - 9:45 to 11:45
- Non peak period 2: - 13:30 to 16:15
- Non peak period 3: - 17:45 to 22:00

Description of Retrofits or Retrocommissioning Undertaken:
Service on demand (SOD) Escalator.
Further analysis on peak periods, and their associated idling times are shown on the next 3 pages, along with a formula for estimating energy savings in any specific escalator.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** Not disclosed
- **Energy usage after retrofit:** Not disclosed
- **Energy saved:**
  - For auto on-off installation: 3,400 KWh each year, per escalator
  - For auto two-speed installation: 2,040 KWh each year, per escalator
- **Cost savings:** Not disclosed
- **Payback period:** Not disclosed

Any additional figures: (see next 3 pages)

Adjusted Idling time at non peak period 1 經調整後非高峰時段1內的空載時間

Start 開始	End 完結	Idling Time (second) 空載時間 (秒), Ti	Adjusted Idling Time (second) 調整後空載時間 (秒), ATi
09:50:27	09:54:05	218	208
09:57:23	10:00:56	213	203
10:05:43	10:08:55	192	182
10:14:52	10:17:43	171	161
10:21:36	10:22:44	68	58
10:26:21	10:29:28	187	177
10:39:43	10:42:25	162	152
10:48:15	10:48:21	6	0
10:52:01	10:53:33	92	82
11:02:13	11:03:17	64	74
11:13:03	11:16:11	188	178
11:19:33	11:22:22	169	159
11:32:25	11:35:55	210	200
11:41:29	11:43:15	106	96
		Subtotal 小計:	1930

Figure F.7: Idling time at non peak period 1, with 10 seconds adjustment to factor in minimum time delay. (EMSD, 2016i)

Adjusted Idling time at non peak period 2 經調整後非高峰時段2內的空載時間

Start 開始	End 完結	Idling Time (second) 空載時間(秒), Ti	Adjusted Idling Time (second) 調整後空載時間(秒), ATi
13:33:16	13:39:12	356	346
13:39:49	13:44:38	289	279
13:48:26	13:53:45	319	309
13:54:45	13:57:08	143	133
14:01:57	14:04:12	135	125
14:08:54	14:10:27	93	83
14:14:53	14:18:26	213	203
14:22:54	14:28:00	306	296
14:32:18	14:36:47	269	259
14:38:32	14:40:14	102	92
14:47:59	14:52:24	265	255
14:53:40	14:57:20	220	210
15:02:52	15:06:05	193	183
15:14:24	15:16:43	139	129
15:20:58	15:26:32	334	324
15:33:55	15:34:46	51	41
15:37:32	15:39:39	127	117
15:43:00	15:45:16	136	126
15:46:42	15:50:28	226	216
15:54:45	15:55:08	23	13
15:56:39	15:59:44	185	175
16:06:42	16:10:38	236	226
		Subtotal 小計:	4140

Figure F.8: Idling time at non peak period 2, with 10 seconds adjustment to factor in minimum time delay. (EMSD, 2016i)

Adjusted Idling time at non peak period 3 經調整後非高峰時段3內的空載時間

Start 開始	End 完結	Idling Time (second) 空載時間(秒), Ti	Adjusted Idling Time (second) 調整後空載時間(秒), ATi
17:47:20	18:07:06	1186	1176
18:08:09	18:19:53	704	694
18:22:43	18:38:09	926	916
18:40:54	18:51:12	618	608
18:52:11	19:04:47	756	746
19:06:59	19:30:04	1385	1375
19:30:44	19:39:48	544	534
19:41:36	19:42:32	56	46
19:43:07	19:59:20	973	963
20:00:36	20:16:23	947	937
20:18:25	20:24:50	385	375
20:27:37	20:52:21	1484	1474
20:53:18	21:04:19	661	651
21:06:33	21:11:38	305	295
21:14:47	21:32:57	1090	1080
21:33:29	21:38:51	322	312
21:41:12	21:41:49	37	27
21:44:54	21:46:34	100	90
21:48:36	22:09:30	1254	1244
		Subtotal 小計:	13543

Figure F.9: Idling time at non peak period 3, with 10 seconds adjustment to factor in minimum time delay. (EMSD, 2016i)

$$\text{Estimate energy saving} = \frac{\text{P x Daily Idling Period (second) 每日空載時間長度(秒) x F}}{3600}$$

估計節能

P is the power consumption of empty escalator; typically 1.5 – 2 kW

P 是行人扶手電梯空載時的功率，一般為1.5 - 2千瓦。

F is energy saving factor; F=1 for Auto On-off control, and F=0.6 for Auto Two-speed control

F是節能因子，在自動開關控制時F=1，在自動兩速控制時F=0.6

Figure F.10: Formula for estimating energy savings (EMSD, 2016i)

F.22 Using a Heat Pump for Hot Water Showers

Source document: (EMSD, 2016g)
Company: Not disclosed
Year completed: Not disclosed
Building Type and Size: Not disclosed
Previous System: The building provided showers to staff. The existing system consisted of 6 gas boilers of 275L and had an annual hot water consumption of 700 m^3.
Description of Retrofits or Retrocommissioning Undertaken:
The existing system was replaced with 2 water-to-water heat pumps of 30kW heating power and 2 storage tanks of 1000L each.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** Not disclosed
- **Energy usage after retrofit:** Not disclosed
- **Energy saved:** 290,000 KWh per year
- **Cost savings:** Not disclosed
- **Payback period:** 5.2 years

F.23 Using a Heat Pump for a Hydrotherapy Pool

Source document: (EMSD, 2016g)
Company: Not disclosed
Year completed: Not disclosed
Building Type and Size: Not disclosed
Previous System: The water in the pool had to be 34+/-1℃The existing system consisted of four 18kW instantaneous electric heaters.
Description of Retrofits or Retrocommissioning Undertaken:
The existing system was replaced with a water-to-water heat pump of 30kW heating power. The heat pump had an average daily coefficient of performance 4.25.
Numbers and Data

- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** Not disclosed
- **Energy usage after retrofit:** Not disclosed
- **Energy saved:** 165,000 KWh per year
- **Cost savings:** Not disclosed
- **Payback period:** 3.8 years

F.24 Using a Heat Pump for an Industrial Laundry Facility

Source document: (EMSD, 2016g)
Company: Not disclosed
Year completed: Not disclosed
Building Type and Size:
Industrial Laundry Facility. Size not disclosed
Previous System:
The industrial laundry facility used a diesel-fueled boiler system. The water was heated to as high as 60°C in one pass.
Description of Retrofits or Retrocommissioning Undertaken:
A high temperature heat pump was installed to preheat water for the existing diesel fueled boiler system.
Numbers and Data

- **Highest daily coefficient of performance:** 4.0
- **Cost of investment in the project:** Not disclosed
- **Energy usage before retrofit:** Not disclosed
- **Energy usage after retrofit:** 30000 KWh
- **Energy saved:** 5500L of diesel per year
- **Cost savings:** Not disclosed
- **Payback period:** 8.6 years

F.25 Hydra Balance System

Source document: (Phoebus Energy, 2016)
Company: Hotel E
Year completed: 2016
Building Type and Size: 4 Star Hotel, 170 rooms
Previous System:
The hotel has retrofitted the Hydra Balance system which is used to reduce energy cost on heating as well as cooling.
Description of Retrofits or Retrocommissioning Undertaken:
The hotel has installed the 475 KW heating capacity Hydra Balance system (heat pump), which is used to reduce energy cost on heating as well as cooling.
Numbers and Data

Cost of investment in the project: Not disclosed
Energy usage before retrofit: Not disclosed
Energy usage after retrofit: 2,500 kWh daily on heating,
1,420 kWh daily on cooling,
Energy saved: Not disclosed
Cost savings: 90,141 HKD or 57% saving,
409 HKD daily on heating,
840 HKD daily on cooling.
Payback period: Not disclosed
Additional facts: 100% reduction on fossil fuel consumption.
Reduced CO_2 global pollutants by 1 million kg.